EPA REGIONS 5 AND 7: PLANTS 9 AND 10

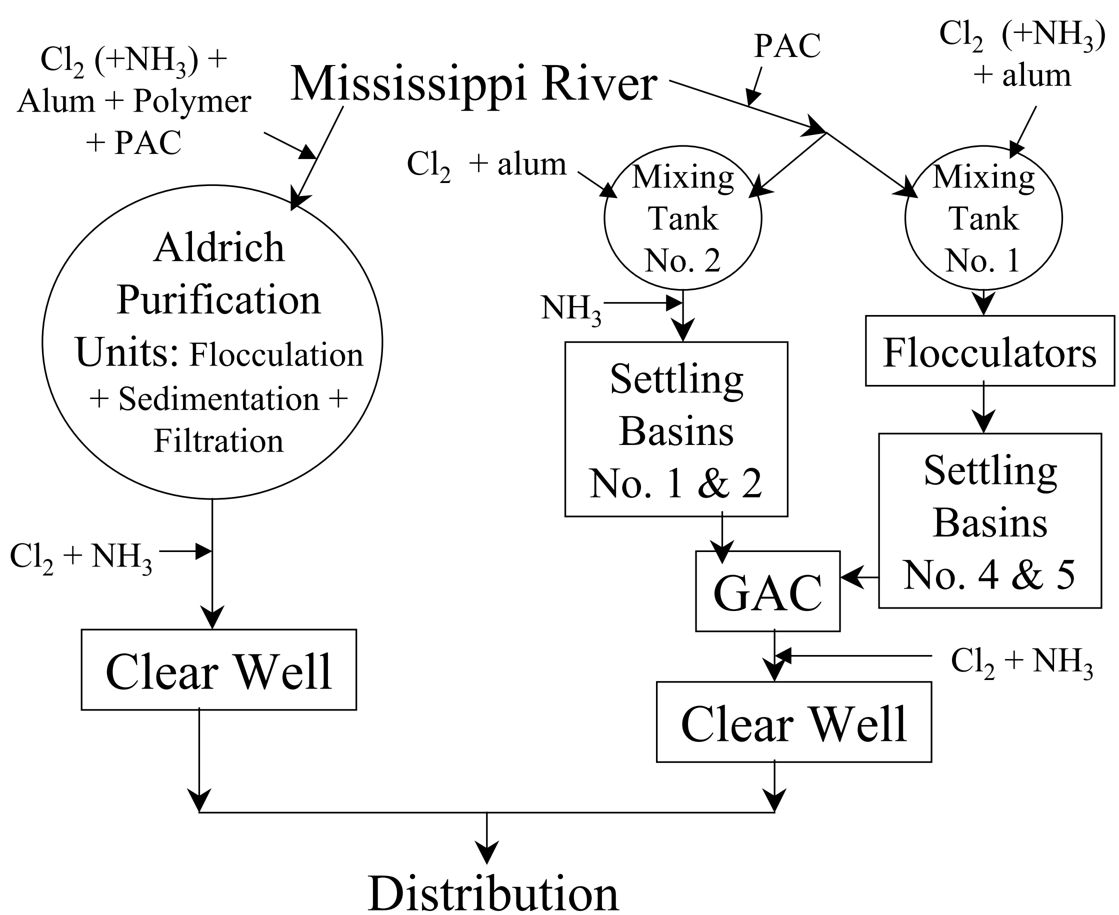
Plant Operations and Sampling

The Mississippi River is the source of water for many drinking-water-treatment plants (WTPs). Plant 10 (in EPA Region 5) treated water from the Mississippi River. In addition, plant 9 (in EPA Region 7) treated water from the Mississippi River; however, the water that was treated at plant 9 was a combination of water from the Mississippi River and another river that flowed into the Mississippi. On January 10, 2001, April 9, 2001, August 27 or September 5, 2001, November 26, 2001, and February 25, 2002, plant 10 and plant 9 were sampled.

Plant 10 had two different treatment trains (Figure 1):

- One train consisted of Aldrich purification units. Chlorine, alum, polymer, and powdered activated carbon (PAC) were added to the raw water. The water underwent flocculation, sedimentation, and filtration. Chlorine and ammonia were added to the filtered water to form chloramines in January and April 2001. Alternatively, chlorine and ammonia were both added to the raw water in November 2001 and February 2002 to form chloramines. During the September 2001 sampling, plant 10 used chlorine only. Many utilities that use chloramines switch back to the use of chlorine only once per year to control the growth of nitrifying bacteria in the distribution system.

Figure 1. Schematic of treatment process at plant 10



- The other train at plant 10 consisted of conventional treatment. PAC was applied to the raw water. Then within this train, there were parallel treatment basins:
  - Chlorine and alum were added at mixing tank number 2. Ammonia (to form chloramines) was added immediately after the mixing tank in January 2001, April 2001, and February 2002, but not during the September 2001 sampling. The water underwent sedimentation in basins 1 and 2. Basins 1 and 2 were out of service for repairs in November 2001.
  - (The raw water for basins 4 and 5 was a mixture of water from the two intakes, one for the Aldrich purification units and the other for the conventional treatment train.) Chlorine and alum were added at mixing tank number 1. No ammonia was added to this portion of the conventional train in January, April or September 2001. Alternatively, chlorine and ammonia were both added at mixing tank number 1 in November 2001 and February 2002 to form chloramines. Chlorinated (or chloraminated) water underwent flocculation and sedimentation (in basins number 4 and 5).
  - The water from all four settling basins was then filtered through granular activated carbon (GAC) filters. The GAC was operated for taste-and-odor control and not for the removal of DBP precursors. Chlorine and ammonia (to form chloramines) was added to the filtered water in January 2001, April 2001, November 2001, and February 2002, but not during the September 2001 sampling, when only chlorine was added.

At plant 9 (Figure 2), initially, the water underwent pretreatment with polymer addition. Then the water was lime softened. The softened water was then chlorinated and treated with ferric sulfate [$Fe_2(SO_4)_3$] in the conditioning chamber. At the end of the conditioning chamber, ammonia was added to form chloramines. The water then passed through a series of settling basins. PAC was added to the effluent of basin #6. The water was then treated with additional ferric sulfate, polymer, chlorine, and ammonia. Finally, the water underwent filtration.

Plant 10 was sampled at the following locations:

<u>Aldrich Purification Units Train</u>

(1) raw water
(2) the filter effluent (January 2001 only)
(3) the clearwell effluent

<u>Conventional Treatment Train</u>

(4) raw water
(5) the effluent of basins 4 and 5
(6) the effluent of basins 1 and 2 (except for November 2001)
(7) the filter effluent
(8) the clearwell effluent (January 2001 only)

<u>Combined Plant</u>

(9) the finished water

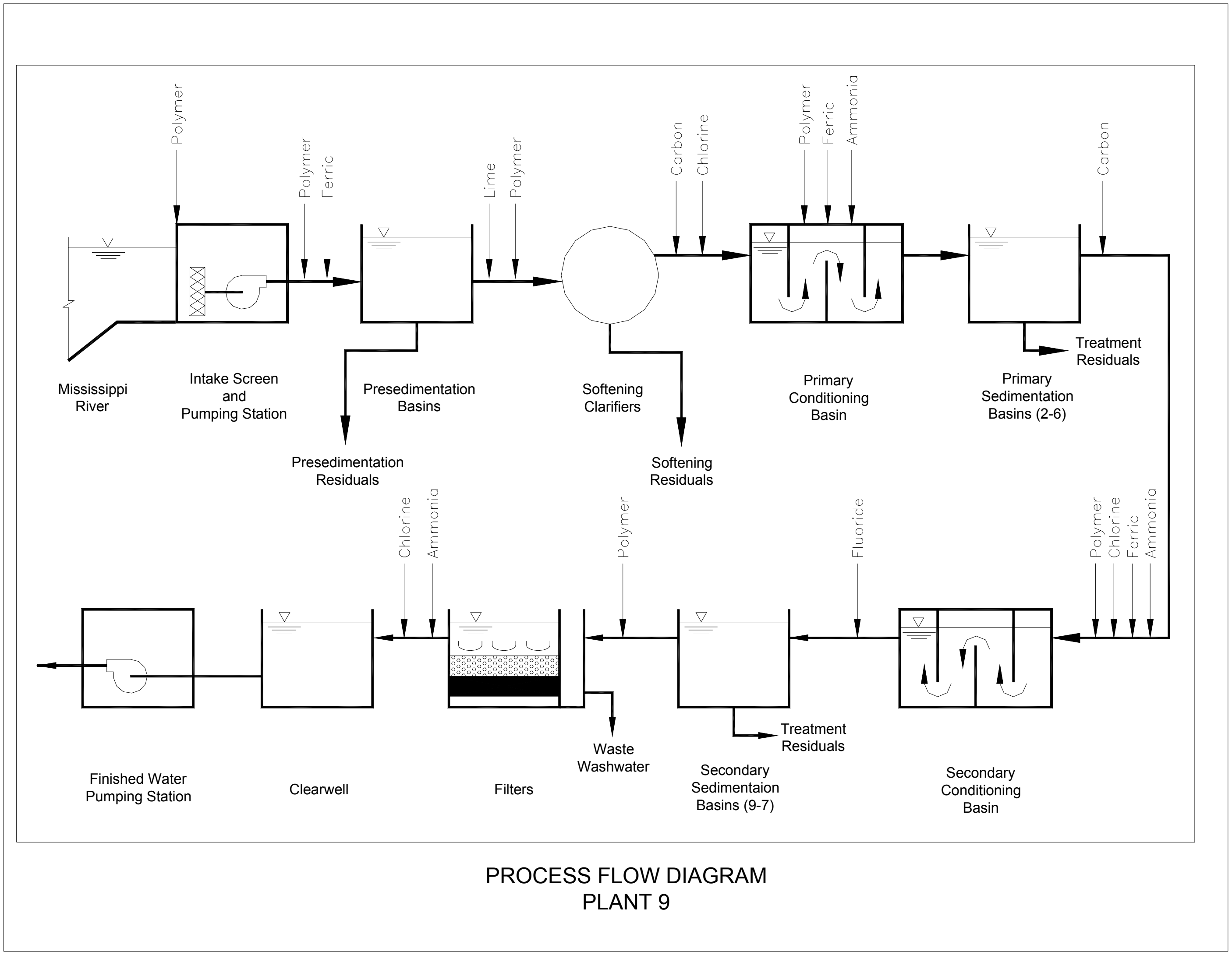


Figure 2. Plant 9 water treatment plant

In addition, finished water from the point of entry was collected and simulated distribution system (SDS) testing was conducted for average and maximum detention times for that time of year (Table 1). In November 2001, a separate SDS sample at maximum detention time was prepared for the University of North Carolina (UNC), which used water from the clearwell of the conventional treatment train. Furthermore, the distribution system was sampled at one to two locations, one representing an average detention time and the other representing a maximum detention time (January 2001 only).

Plant 9 was sampled at the following locations:

(1) raw water
(2) softened water
(3) water from the primary conditioner
(4) the effluent of basin #6
(5) the filter influent
(6) and the finished water

In addition, finished water was collected and SDS testing was conducted for average and maximum detention times for that time of year (Table 1). Furthermore, the distribution system was sampled at two locations, one representing an average detention time and the other representing a maximum detention time.

Table 1. SDS holding times at Mississippi River WTPs

Sample	1/10/01	4/9/01	8/27 or 9/5/01	11/26/01	2/25/02
Plant 10 average detention time	4 hr	4 hr	4 hr	4 hr	4 hr
Plant 10 maximum detention time	5 days	5 days	5 days	5 days	5 days
Plant 9 average detention time	3 days	3 days	2 days	2 days	2 days
Plant 9 maximum detention time	6 days	6 days	3 days	4 days	3 days

On the day of sampling, information was collected on the operations at each plant (Tables 2-3).

Table 2. Operational information at plant 10

Parameter	1/10/01	4/9/01	9/5/01	11/26/01	2/25/02
Aldrich Purification Units Train					
Plant flow for this train (mgd)	8	8	11	10	8
Chlorine dose at plant influent (mg/L as Cl_2)	10	17	16	10	9.7
Ammonia dose at plant influent (mg/L as NH_3-N)	0	0	0	2.0	1.7
Alum dose at plant influent (mg/L)	96	96	35	60.4	76.6
Polymer dosage at plant influent (mg/L)	3.7	3.5	2.1[a]	2.0	3.5
PAC dosage at plant influent (mg/L)	1	1.8	0.5	1.2	3.0
Permanganate dose at plant influent (mg/L)	0	0	2.2	0	0
Chlorine dose at combined filter eff. (mg/L as Cl_2)	2	1.6	3.6	0.8	0
NH_3 dose at combined filter eff. (mg/L as NH_3-N)	0.6	0.8	0	0.8	0
Conventional Treatment Train					
PAC dosage at intake (mg/L)	1	1	0.7	0	0
Permanganate dose at intake (mg/L)	0	0	2.0	0	1.7

Table 2 (continued)

Parameter	1/10/01	4/9/01	9/5/01	11/26/01	2/25/02
Train for Basins 1 and 2					
Plant flow for these basins (mgd)	10	11	11	0	8
Chlorine dose at mixing tank no. 2 (mg/L as Cl_2)	6	6	6.7	---	7.5
NH_3 dose immediately after mixing tank no. 2 (mg/L as NH_3-N)	1	1	0	---	1.5
Alum dose at mixing tank number 2 (mg/L)	54	50	53.2	---	51
Train for Basins 4 and 5					
Plant flow for these basins (mgd)	22	20.6	25.8	27.5	20.0
Chlorine dose at mixing tank no. 1 (mg/L as Cl_2)	6	14	9.1	4.9	5.7
NH_3 dose at mixing tank no. 1 (mg/L as NH_3-N)	0	0	0	0.9	1.2
Alum dose at mixing tank number 1 (mg/L)	54	50	45.6	55.4	51
Polymer dosage at mixing tank number 1 (mg/L)	0	1.1	0	0	0
Combined Conventional Treatment Train					
GAC filter loading rate (gpm/sq ft)	NA[b]	2	2	2	2
GAC empty bed contact time (min)	NA	5.6	5.6	5.6	5.6
Chlorine dose at combined filter eff. (mg/L as Cl_2)	2	3	3.6	3.7	1.9
NH_3 dose at combined filter eff. (mg/L as NH_3-N)	0.6	0.6	0	0.7	0.5

[a]At intake
[b]NA = Not available

Table 3. Operational information at plant 9

Parameter	1/10/01	4/9/01	8/27/01	11/26/01	2/25/02
Plant flow (mgd)	122	88-94	82	70	84
Polymer dosage at plant influent (mg/L)	1.0	3.0	2.0	2.0	2.5
Lime dosage in softening basins (mg/L)	108	77	101	101	103
Chlorine dose at cond. chamber (mg/L as Cl_2)	2.52	2.3	2.88	2.16	2.0
$Fe_2(SO_4)_3$ dose at conditioning chamber (mg/L)	6.8	6.8	8.6	3.4	3.4
Polymer dosage at conditioning chamber (mg/L)	0.5	1.5	1.0	1.0	1.0
NH_3 dose at end of cond. chamber (mg/L as NH_3-N)	1.44	1.2	1.92	1.68	1.6
PAC dosage at Basin 6 effluent (mg/L)	2.4	6.0	6.0	1.2	1.2[a]
$Fe_2(SO_4)_3$ dose at influent to Basin 9 (mg/L)	8.6	6.8	6.8	3.4	0
Polymer dosage at influent to Basin 9 (mg/L)	1.0	0.4	0.4	0.4	0
Chlorine dose at influent to Basin 9 (mg/L as Cl_2)	1.92	2.9	2.4	2.16	2.3
Ammonia dose at inf. to Basin 9 (mg/L as NH_3-N)	1.44	1.6	1.92	1.8	1.8
Chlorine dose at clearwell effluent (mg/L as Cl_2)	0	0	0.24	0	0
Ammonia dose at clearwell eff. (mg/L as NH_3-N)	0	0	0.12	0	0

[a]PAC dosage at Basin 1 influent

Water Quality

On the day of sampling, information was collected on water quality at each plant (Tables 4-5). Data were collected for total organic carbon (TOC) and ultraviolet (UV) absorbance (Tables 6-7). The raw water in January 2001, April 2001, summer (August or September) 2001, November 2001, and February 2002 at plant 10 was somewhat higher in TOC than at plant 9 (4.0-5.9 versus 3.4-5.0 mg/L). Nonetheless, both utilities had a moderate loading of DBP precursors.

At plant 10, in the Aldrich purification units in January 2001, April 2001, September 2001, November 2001, and February 2002, 14-32 % of the TOC and 18-47 % of the UV was removed. At plant 10, in the conventional treatment train in January 2001, April 2001, September 2001, November 2001, and February 2002, coagulation removed 17-27 % of the TOC and filtration removed another 2-17 %. The overall TOC removal in the conventional treatment train was 28-34 %. In addition, the overall UV removal in the conventional treatment train was 41-62 %.

At plant 9, in April 2001, August 2001, November 2001, and February 2002, softening removed 19-28 % of the TOC, whereas in January 2001 no TOC was initially removed during the softening process. At plant 9, with downstream coagulation and filtration, the overall TOC removal on these three sample dates was 17-34 %. In addition, the overall UV removal was 11-45 %.

Tables 8-9 show the values of miscellaneous other water quality parameters in the raw water at plant 10 and plant 9, respectively. The raw water in January 2001, April 2001, summer (August or September) 2001, November 2001, and February 2002 at plant 9 was higher in bromide than at plant 10 (0.06-0.36 versus 0.05-0.08 mg/L). Nonetheless, both utilities had a moderate loading of inorganic DBP precursors.

Table 4. Water quality information at plant 10

	pH					Temperature (ºC)					Disinfectant Residual[a] (mg/L)				
Location	1/10/01	4/9/01	9/5/01	11/26/01	2/25/02	1/10/01	4/9/01	9/5/01	11/26/01	2/25/02	1/10/01	4/9/01	9/5/01	11/26/01	2/25/02
Aldrich Purification Units Train															
Raw water	8.01	8.32	8.21	8.5	8.67	1.5	13.1	28.1	13.3	7.5	---	---	---	---	---
Filter eff.	7.67	7.51	7.39	7.8	7.84	2.7	14.7	29.8	14.2	8.2	1.3	2.4	*2.1*	5.4	5.0
Clearwell	7.56	7.50	7.60	7.6	7.70	---	14.9	28.4	13.5	9.5	3.7	4.2	*4.0*	5.6	4.9
Conventional Treatment Train															
Raw water	8.03	8.38	8.33	8.5	8.68	0.7	13.3	28.0	14.7	6.4	---	---	---	---	---
Basins 4&5	7.38	7.36	7.24	7.8	7.79	0.3	14.0	29.2	16.1	5.8	*1.9*	*3.3*	*2.4*	3.3	5.3
Basins 1&2	7.49	7.47	7.22	NS	7.80	0.4	14.1	27.4	NS	5.6	4.7	4.1	*0.7*	NS	3.9
Filter eff.	7.37	7.37	7.16	7.6	7.75	3.5	14.7	28.3	13.2	6.1	0.3[b]	0.2[b]	*0.4*	0.4	1.1
Clearwell	7.45	7.54	7.70	7.5	7.64	2.6	15.0	28.0	13.1	7.9	3.2	3.6	*3.4*	3.8	3.6
Combined Plant															
Finished	7.48	7.41	7.68	7.5	7.69	3.0	14.4	27.5	12.3	6.5	3.7	3.7	*3.5*	3.4	3.6
DS[c]/ave	7.53	7.48	7.54	7.4	7.38	2.4	13.1	26.4	13.5	7.4	2.4	3.3	*3.1*	3.1	3.0
DS/max	7.47	NS[d]	NS	NS	NS	10.4	NS	NS	NS	NS	1.7	NS	NS	NS	NS
SDS/ave	7.51	7.46	7.63	7.5	7.65	2.9	14.8	27.6	12.2	6.3	3.5	3.5	*2.9*	3.2	3.0
SDS/max	7.52	7.39	7.56	7.5	7.57	2.5	15.3	26.4	11.8	5.6	2.9	1.8	*0.3*	0.9	2.3
SDS/max for UNC	---	---	---	7.5	---	---	---	---	11.5	---	---	---	---	1.0	---

[a]Chlorine residuals (values shown in italics) at Basins 4 & 5 effluent in January and April 2001, and all sample locations in September 2001; chloramine residuals at other locations.
[b]GAC filters removed chlorine.
[c]DS = Distribution system
[d]NS = Not sampled

Table 5. Water quality information at plant 9

	pH					Temperature (ºC)					Disinfectant Residual[a] (mg/L)				
Location	1/10/01	4/9/01	8/27/01	11/26/01	2/25/02	1/10/01	4/9/01	8/27/01	11/26/01	2/25/02	1/10/01	4/9/01	8/27/01	11/26/01	2/25/02
Raw	8.10	8.00	8.64	8.26	8.24	1.1	14.4	28.3	12.8	8.3	---	---	---	---	---
Softened	9.97	10.2	9.82	10.1	9.37	1.5	14.4	27.0	13.3	8.6	---	---	---	---	---
1^o cond.	9.74	9.85	9.66	9.97	9.35	1.4	15.6	26.9	13.3	8.6	*1.60*	*1.50*	*1.10*	2.20	1.60
Basin #6	9.66	9.68	9.76	9.65	9.32	2.2	15.6	26.1	13.3	9.4	1.60	1.10	0.95	1.50	1.55
Filter inf.	9.21	9.31	9.34	9.39	9.12	2.2	15.6	26.7	14.4	9.8	2.50	2.25	2.25	2.65	2.60
Finished	9.59	9.70	9.23	9.35	9.12	1.4	15.6	27.2	13.3	8.9	2.45	2.25	2.40	2.65	2.60
DS/ave	9.74	9.35	9.15	9.10	9.23	3.7	18.9	28.0	13.1	9.8	2.45	2.15	2.25	2.30	2.55
DS/max	9.48	9.33	9.38	9.20	9.28	4.0	18.9	28.4	13.2	9.8	2.40	2.15	2.10	2.20	2.40
SDS/ave	9.18	9.26	9.19	9.36	8.93	8.9	16.0	24.4	15.6	7.8	2.45	2.20	2.20	2.40	2.45
SDS/max	9.09	9.26	9.29	9.38	8.9	6.7	16.5	25.0	13.9	7.2	2.35	2.10	2.10	2.30	2.4

[a]Chlorine residuals (values shown in italics) at primary (1^o) conditioner in January, April, and August 2001; chloramine residuals at other locations.

Table 6. TOC and UV removal at plant 10

Location	TOC (mg/L)	UV[a] (cm^{-1})	SUVA[b] (L/mg-m)	Removal/Unit (%) TOC	Removal/Unit (%) UV	Removal/Cumulative (%) TOC	Removal/Cumulative (%) UV
01/10/2001							
Aldrich Raw	4.83	0.113	2.34	---	---	---	---
Aldrich Filter Eff.	3.57	0.063	1.76	26%	44%	26%	44%
Conventional Raw	5.11	0.127	2.49	---	---	---	---
Basins 4 & 5 Eff.	4.12	0.057	1.38	19%	55%	19%	55%
Basins 1 & 2 Eff.	4.04	0.079	1.96	21%	38%	21%	38%
Combined Filter Eff.[c]	3.42	0.053	1.55	17%	7.0%	33%	58%
04/09/2001							
Aldrich Raw	4.01	0.093	2.32	---	---	---	---
Aldrich Clearwell Eff.	2.86	0.051	1.78	29%	45%	29%	45%
Conventional Raw	4.22	0.103	2.44	---	---	---	---
Basins 4 & 5 Eff.	3.08	0.035	1.14	27%	66%	27%	66%
Basins 1 & 2 Eff.	3.11	0.053	1.70	26%	49%	26%	49%
Combined Filter Eff.	3.03	0.039	1.29	1.6%	-11%	28%	62%
09/05/2001							
Aldrich Raw	5.45	0.148	2.72	---	---	---	---
Aldrich Clearwell Eff.	4.68	0.078	1.67	14%	47%	14%	47%
Conventional Raw	5.87	0.152	2.59	---	---	---	---
Basins 4 & 5 Eff.	4.39	0.066	1.50	25%	57%	25%	57%
Basins 1 & 2 Eff.	4.89	0.075	1.53	17%	51%	17%	51%
Combined Filter Eff.	4.22	0.067	1.59	3.9%	-1.5%	28%	56%
11/26/2001							
Aldrich Raw	4.98	0.122	2.45	---	---	---	---
Aldrich Clearwell Eff.	3.64	0.100	2.75	27%	18%	27%	18%
Conventional Raw	5.04	0.127	2.52	---	---	---	---
Basins 4 & 5 Eff.	4.0	0.089	2.23	21%	30%	21%	30%
Basins 1 & 2 Eff.	NS	NS	---	---	---	---	---
Combined Filter Eff.	3.43	0.070	2.04	14%	21%	32%	45%
02/25/2002							
Aldrich Raw	4.52	0.099	2.19	---	---	---	---
Aldrich Clearwell Eff.	3.08	0.075	2.44	32%	24%	32%	24%
Conventional Raw	4.91	0.111	2.26	---	---	---	---
Basins 4 & 5 Eff.	3.67	0.083	2.26	25%	25%	25%	25%
Basins 1 & 2 Eff.	3.57	0.072	2.02	27%	35%	27%	35%
Combined Filter Eff.	3.24	0.065	2.01	12%	22%	34%	41%

[a]UV = Ultraviolet absorbance reported in units of "inverse centimeters" (APHA, 1998)

[b]SUVA (L/mg-m) = Specific ultraviolet absorbance = 100*UV (cm^{-1})/DOC (mg/L) or UV (m^{-1})/DOC (mg/L), where DOC = dissolved organic carbon, which typically = 90-95% TOC (used TOC values in calculating SUVA) (e.g., UV = 0.113/cm = 0.113/(0.01 m) = 11.3/m, DOC = 4.83 mg/L, SUVA = (11.3 m^{-1})/(4.83 mg/L) = 2.34 L/mg-m)

[c]Removal/unit compared to basins 4 & 5 effluent

Table 7. TOC and UV removal at plant 9

Location	TOC (mg/L)	UV[a] (cm^{-1})	SUVA[b] (L/mg-m)	Removal/Unit (%) TOC	Removal/Unit (%) UV	Removal/Cumulative (%) TOC	Removal/Cumulative (%) UV
01/10/2001							
Raw	3.39	0.063	1.86	---	---	---	---
Softened Water	3.51	0.049	1.40	-3.5%	22%	-3.5%	22%
Primary Conditioner	3.09	0.055	1.78	12%	-12%	8.8%	13%
Basin #6 Eff.	3.20	0.056	1.75	-3.6%	-1.8%	5.6%	11%
Filter Inf.	2.85	0.059	2.07	11%	-5.4%	16%	6.3%
Finished Water	2.80	0.056	2.00	1.8%	5.1%	17%	11%
04/09/2001							
Raw	4.96	0.137	2.76	---	---	---	---
Softened Water	3.58	0.076	2.12	28%	45%	28%	45%
Primary Conditioner	3.61	0.078	2.16	-0.8%	-2.6%	27%	43%
Basin #6 Eff.	4.05	0.089	2.20	-12%	-14%	18%	35%
Filter Inf.	3.51	0.078	2.22	13%	12%	29%	43%
Finished Water	3.49	0.076	2.18	0.6%	2.6%	30%	45%
08/27/2001							
Raw	4.22	0.093	2.20	---	---	---	---
Softened Water	3.40	0.068	2.00	19%	27%	19%	27%
Primary Conditioner	3.19	0.052	1.63	6.2%	24%	24%	44%
Basin #6 Eff.	2.97	0.058	1.95	6.9%	-12%	30%	38%
Filter Inf.	2.79	0.056	2.01	6.1%	3.4%	34%	40%
Finished Water	2.77	0.058	2.09	0.7%	-3.6%	34%	38%
11/26/2001							
Raw	3.61	0.082	2.27	---	---	---	---
Softened Water	2.69	0.047	1.75	25%	43%	25%	43%
Primary Conditioner	2.89	0.054	1.87	-7.4%	-15%	20%	34%
Basin #6 Eff.	2.43	0.050	2.06	16%	7%	33%	39%
Filter Inf.	2.29	0.051	2.23	5.8%	-2.0%	37%	38%
Finished Water	2.37	0.053	2.24	-3.5%	-3.9%	34%	35%
02/25/2002							
Raw	3.37	0.074	2.20	---	---	---	---
Softened Water	2.67	0.049	1.84	21%	34%	21%	34%
Primary Conditioner	3.34	0.050	1.50	-25%	-2.0%	1%	32%
Basin #6 Eff.	2.50	0.051	2.04	25%	-2.0%	26%	31%
Filter Inf.	2.55	0.054	2.12	-2.0%	-5.9%	24%	27%
Finished Water	2.48	0.055	2.22	2.7%	-1.9%	26%	26%

[a]UV = Ultraviolet absorbance reported in units of "inverse centimeters" (APHA, 1998)

[b]SUVA (L/mg-m) = Specific ultraviolet absorbance = 100*UV (cm^{-1})/DOC (mg/L) or UV (m^{-1})/DOC (mg/L), where DOC = dissolved organic carbon, which typically = 90-95% TOC (used TOC values in calculating SUVA) (e.g., UV = 0.063/cm = 0.063/(0.01 m) = 6.3/m, DOC = 3.39 mg/L, SUVA = (6.3 m^{-1})/(3.39 mg/L) = 1.86 L/mg-m)

On the January 2001, April 2001, September 2001, November 2001, and February 2002 samplings, the raw water at plant 10 contained up to 0.16 mg/L of ammonia (Table 8). Theoretically, it takes 7.6 mg/L of chlorine to breakpoint chlorinate 1.0 mg/L of ammonia-nitrogen. The theoretical inorganic chlorine demand (up to 1.2 mg/L) was significantly less than the initial chlorine dose applied at each of the trains when prechlorination was practiced (6-17 mg/L) (Table 2).

Table 8. Miscellaneous water quality parameters in raw water at plant 10

Location	Bromide (mg/L)	Alkalinity (mg/L)	Ammonia (mg/L as N)	Chlorine Demand[a] (mg/L)
01/10/2001				
Aldrich Train Raw	0.08	199	0.15	1.1
Conventional Train Raw	0.07	199	0.16	1.2
04/09/2001				
Aldrich Train Raw	0.05	176	ND[b]	0
Conventional Train Raw	0.05	173	0.08	0.6
09/05/2001				
Aldrich Train Raw	0.07	148	0.04	0.3
Conventional Train Raw	0.07	149	ND	0
11/26/2001				
Aldrich Train Raw	0.05	189	0.05	0.4
Conventional Train Raw	0.05	186	0.07	0.5
02/25/2002				
Aldrich Train Raw	0.05	175	0.06	0.5
Conventional Train Raw	0.05	188	0.14	1.1

[a]Chlorine demand from ammonia = 7.6 * ammonia (mg/L as N)

[b]ND = Not detected

Table 9. Miscellaneous water quality parameters in raw water at plant 9

Date	Bromide (mg/L)	Alkalinity (mg/L)	Ammonia (mg/L as N)	Chlorine Demand[a] (mg/L)
01/10/2001	0.19	221	0.37	2.8
04/09/2001	0.06	99	0.05	0.4
08/27/2001	0.1	175	ND	0
11/26/2001	0.2	182	0.07	0.5
02/25/2002	0.36	171	0.1	0.8

[a]Chlorine demand from ammonia = 7.6 * ammonia (mg/L as N)

In January 2001, the raw water at plant 9 contained 0.4 mg/L of ammonia, whereas in April 2001, August 2001, November 2001, and February 2002 it only had up to 0.1 mg/L of ammonia (Table 9). The theoretical inorganic chlorine demand in January 2001 (2.8 mg/L) was somewhat higher than the initial chlorine dose applied at the conditioning chamber (2.5 mg/L) (Table 3). Alternatively, the theoretical inorganic chlorine demand in February 2002 (0.8 mg/L) was lower than the initial chlorine dose applied at the conditioning chamber (2.0 mg/L).

DBPs

Tables 10 and 11 (1/10/01), Tables 13 and 14 (4/9/01), Tables 16 and 17 (8/27-9/5/01), Tables 18 and 19 (11/26/01), and Tables 22 and 23 (2/25/02) show results for the halogenated organic DBPs that were analyzed for at Metropolitan Water District of Southern California (MWDSC). Table 12 (1/10/01) and Table 20 (11/26/01) show results for additional target DBPs that were analyzed for at UNC. Table 20 (11/26/01) show results for halogenated furanones that were analyzed for at UNC. Table 15 (4/9/01 [plant 10], 8/27/01 [plant 9], and 2/25/02 [plant 10]) shows results from broadscreen analyses conducted at the U.S. Environmental Protection Agency (USEPA).

Summary of Tables for DBPs for Mississippi River WTPs

DBP Analyses (Laboratory)	1/10/01	4/9/01	8/27 or 9/5/01	11/26/01	2/25/02
Halogenated organic DBPs (MWDSC)	Tables 10-11	Tables 13-14	Tables 16-17	Tables 18-19	Tables 22-23
Additional target DBPs (UNC)	Table 12			Table 20	
Halogenated furanones (UNC)				Table 21	
Broadscreen analysis (USEPA)		Table 15[a]	Table 15[b]		Table 15[a]

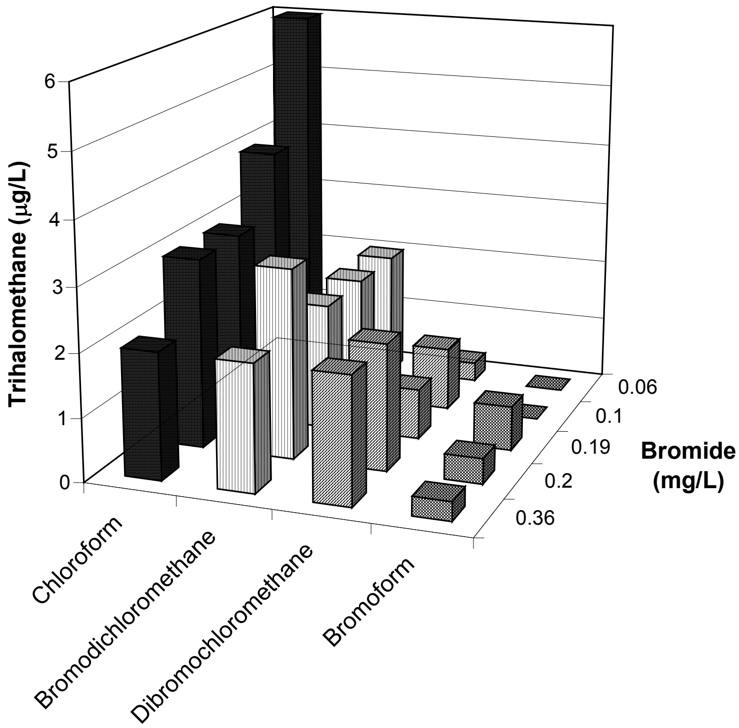
[a]Plant 10
[b]Plant 9

Halomethanes. Chlorine and/or chloramine disinfection at plant 10 in January and April 2001 resulted in the formation of 71-84 and 54 µg/L of the four regulated trihalomethanes (THM4) in the Aldrich purification units and in basins 4 and 5, respectively. THM formation was lower in the effluent of basins 1 and 2 in January (30 µg/L of chloroform) and April 2001 (31 µg/L of THM4) because free chlorine was only present in mixing tank number 2 before ammonia addition (upstream of basins 1 and 2). Chlorine only disinfection in September 2001 resulted in the formation of 144, 144, and 174 µg/L of THM4 in the Aldrich purification units, in basins 4 and 5, and in basins 1 and 2, respectively. Another major difference between the three seasons was temperature: 0.3-3ºC in January 2001, 13-15ºC in April 2001, and 26-30ºC in September 2001 (Table 4). Thus, THM formation was significantly higher in September 2001 due to the presence of only free chlorine (no chloramines) and the warmer water temperature. In contrast, the use of chloramines only at plant 10 in November 2001 and February 2002 resulted in the formation of 12-19 and 8-14 µg/L of THM4 in the Aldrich purification units and in basins 4 and 5, respectively.

Chlorine/chloramine disinfection at plant 9 in January 2001, April 2001, August 2001, November 2001, and February 2002 resulted in the formation of 6-8 µg/L of THM4. There was no seasonal variability in the concentration of THM4 at this plant during this time period. The very low concentration of THMs at plant 9 suggests that there was minimal free chlorine contact time prior to ammonia addition.

Although there were large differences in the total amounts of THMs formed, both WTPs produced a high percentage of the THMs as chloroform, followed by bromodichloromethane, when the raw-water bromide was less than or equal to 0.1 mg/L. Figure 3 shows the impact of bromide on THM speciation at plant 9. As the concentration of bromide increased, the formation of chloroform decreased and the formation of dibromochloromethane increased.

Figure 3. Impact of bromide on THM speciation in finished water at plant 9



Dichloroiodomethane was detected at plant 10 in November 2001 and February 2002. Dichloroiodomethane, bromochloroiodomethane, and chlorodiiodomethane (February only) were detected at plant 9 in November 2001 and February 2002. Bromide was at its highest in the influent of plant 9 in the latter two months. In addition, two of the iodinated THMs were detected by the broadscreen gas chromatography/mass spectrometry (GC/MS) methods at both WTPs (dichloroiodomethane and bromochloroiodomethane; Table 15).

Dibromomethane, a volatile organic compound (VOC), was detected (0.13 µg/L)—slightly above the minimum reporting level (MRL) (0.11 µg/L)—in a SDS sample of plant 9 in January 2001. In other research, this dihalogenated methane had been detected in a high-bromide water that had been disinfected with chloramines (Krasner et al., 1996). In addition, bromomethane was detected at its MRL (0.2 µg/L) in a plant 9 distribution system sample in November 2001.

Table 10. DBP results at plant 10 (1/10/01)

01/10/2001	MRL[a]	Aldrich[b]			Conventional[b]					Combined Plant[b]				
Compound	µg/L	Raw	Filt Eff	Clearwell	Raw	Basins 4&5	Basins 1&2	Filt Eff	Clearwell	Finished	DS/Ave	DS/Max	SDS/Ave	SDS/Max
Halomethanes														
Chloromethane	0.15	ND[c]		ND	ND	ND		ND	ND	ND	ND		ND	
Bromomethane	0.20	ND		ND	ND	ND		ND	ND	ND	ND		ND	
Bromochloromethane	0.14	ND		ND	ND	ND		ND	ND	ND	ND		ND	
Dibromomethane	0.11	ND		ND	ND	ND		ND	ND	ND	ND		ND	
Chloroform[d]	0.1	0.1	60	60	0.1	40	30	45	40	45	50	60	45	60
Bromodichloromethane[d]	0.10	ND	NR[e]	20	0.1	12	NR	13	12	13	15	NR	14	NR
Dibromochloromethane[d]	0.07	ND	NR	4	ND	2	NR	2	2	2	2	NR	2	NR
Bromoform[d]	0.6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
THM4[f]		0.1	NR	84	0.2	54	NR	60	54	60	67	NR	61	NR
Dichloroiodomethane	0.25	ND	NR	ND	ND	ND	NR	ND	ND	ND	ND	NR	ND	NR
Bromochloroiodomethane	0.20	ND	NR	ND	ND	ND	NR	ND	ND	ND	ND	NR	ND	NR
Dibromoiodomethane	0.6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chlorodiiodomethane	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromodiiodomethane	0.6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Iodoform	0.14	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Carbon tetrachloride	0.06	ND		0.3	ND	ND		ND	ND	0.07	0.1		0.08	
Haloacetic acids														
Monochloroacetic acid[d]	2		10	10		8.8	1.3	7.8	6.5	6.0	6.9		7.2	
Monobromoacetic acid[d]	1		1.0	ND		ND	ND	ND	ND	ND	ND		ND	
Dichloroacetic acid[d]	1		29	29		24	19	21	23	24	24		24	
Bromochloroacetic acid[d]	1		6.1	6.0		4.6	3.7	4.4	4.9	5.1	5.1		4.8	
Dibromoacetic acid[d]	1		1.0	1.0		ND	ND	ND	ND	ND	ND		ND	
Trichloroacetic acid[d]	1		54	55		44	22	45	40	43	44		35	
Bromodichloroacetic acid	1		11	10		9.1	5.3	9.2	8.5	9.1	8.8		8.2	
Dibromochloroacetic acid	1		1.7	1.7		1.4	1.0	1.3	1.2	1.4	1.4		1.0	
Tribromoacetic acid	2		ND	ND		ND	ND	ND	ND	ND	ND		ND	
HAA5[g]			95	95		77	42	74	70	73	75		66	
HAA9[h]			114	113		92	52	89	84	89	90		80	
DXAA[i]			36	36		29	23	25	28	29	29		29	
TXAA[j]			67	67		55	28	56	50	54	54		44	
Haloacetonitriles														
Chloroacetonitrile	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromoacetonitrile	0.10	ND	ND	1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dichloroacetonitrile[d]	0.10	ND	4	4	ND	3	2	2	2	2	3	3	2	3
Bromochloroacetonitrile[d]	0.10	ND	2	2	ND	1	0.5	0.5	0.6	0.7	0.9	1	0.7	1
Dibromoacetonitrile[d]	0.10	ND	0.2	0.2	ND	0.1	ND	ND	ND	0.1	0.1	0.1	0.1	0.1
Trichloroacetonitrile[d]	0.10	ND	0.5	0.6	0.1	ND	0.2	0.4	0.3	0.4	0.4	ND	ND	ND
Haloketones														
Chloropropanone	0.10	ND	ND	ND	ND	ND	ND	ND	0.2	0.2	ND	ND	ND	ND
1,1-Dichloropropanone[d]	0.10	ND	1	1	ND	0.9	1	0.7	0.8	0.8	0.9	1	0.8	1
1,3-Dichloropropanone	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dibromopropanone	N/A			NR	NR	NR		NR	NR	NR	NR		NR	
1,1,1-Trichloropropanone[d]	0.10	ND	4	4	ND	3	2	3	3	3	3	3	3	3
1,1,3-Trichloropropanone	0.10	ND	0.1	0.1	ND	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.1	0.1
1-Bromo-1,1-dichloropropanone	N/A			NR	NR	NR		NR	NR	NR	NR		NR	
1,1,1-Tribromopropanone	N/A			NR	NR	NR		NR	NR	NR	NR		NR	
1,1,3-Tribromopropanone	N/A			NR	NR	NR		NR	NR	NR	NR		NR	
1,1,3,3-Tetrachloropropanone	0.10	ND	0.6	0.3	ND	0.4	0.3	0.2	0.2	0.2	0.2	0.3	0.4	0.3
1,1,3,3-Tetrabromopropanone	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Haloacetaldehydes														
Dichloroacetaldehyde	0.16	ND	5	5	ND	4	2	4	4	4	4	4	4	5
Bromochloroacetaldehyde	0.10	ND	1	1	ND	1	1	0.9	1	1	1	2	1	2
Chloral hydrate[d]	0.10	ND	4	5	ND	3	1	2	3	3	4	4	3	4
Tribromoacetaldehyde	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Halonitromethanes														
[d] Bromonitromethane	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dichloronitromethane	N/A			NR	NR	NR		NR	NR	NR	NR		NR	
Dibromonitromethane	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloropicrin	0.10	ND	1	1	ND	0.8	0.9	0.8	0.8	0.8	0.9	1	0.8	1
Miscellaneous Compounds														
Methyl ethyl ketone	N/A	NR		NR	NR	NR		NR	NR	NR	NR		NR	
Methyl *tertiary* butyl ether	0.16	ND		ND	ND	ND		ND	ND	ND	ND		ND	
Benzyl chloride	N/A	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR

Table 11. DBP results at Plant 9 (1/10/01)

01/10/2001	MRL[a]	Plant 9[k]								
Compound	µg/L	Raw	1° Cond	Basin #6	Filt Inf	Finished	DS/Ave	DS/Max	SDS/Ave	SDS/Max
Halomethanes										
Chloromethane	0.15	ND[c]	ND	ND		ND	ND		ND	
Bromomethane	0.20	ND	ND	ND		ND	ND		ND	
Bromochloromethane	0.14	ND	ND	ND		ND	ND		ND	
Dibromomethane	0.11	ND	ND	ND		ND	ND		0.13	
Chloroform[d]	0.1	ND	1	2	3	3	3	3	3	3
Bromodichloromethane[d]	0.10	0.1	0.5	0.7	NR[e]	2	2	NR	2	NR
Dibromochloromethane[d]	0.07	ND	0.2	0.3	NR	0.8	1	NR	1	NR
Bromoform[d]	0.6	ND	ND	ND	ND	0.7	1	1	0.7	0.8
THM4[f]		0.1	2	3	NR	7	7	NR	7	NR
Dichloroiodomethane	0.25	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromochloroiodomethane	0.20	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dibromoiodomethane	0.6	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chlorodiiodomethane	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromodiiodomethane	0.6	ND	ND	ND	ND	ND	ND	ND	ND	ND
Iodoform	0.14	ND	ND	ND	ND	ND	ND	ND	ND	ND
Carbon tetrachloride	0.06	ND	ND	ND		ND	ND		ND	
Haloacetic acids										
Monochloroacetic acid[d]	2		ND	ND		ND	ND		ND	
Monobromoacetic acid[d]	1		ND	ND		ND	ND		ND	
Dichloroacetic acid[d]	1		2.2	2.5		3.1	3.4		3.5	
Bromochloroacetic acid[d]	1		1.0	1.1		1.4	1.6		1.5	
Dibromoacetic acid[d]	1		1.0	1.2		1.3	1.7		1.5	
Trichloroacetic acid[d]	1		ND	ND		ND	ND		ND	
Bromodichloroacetic acid	1		ND	ND		ND	ND		ND	
Dibromochloroacetic acid	1		ND	ND		ND	ND		ND	
Tribromoacetic acid	2		ND	ND		ND	ND		ND	
HAA5[g]			3.2	3.7		4.4	5.1		5.0	
HAA9[h]			4.2	4.8		5.8	6.7		6.5	
DXAA[i]			4.2	4.8		5.8	6.7		6.5	
TXAA[j]			ND	ND		ND	ND		ND	
Haloacetonitriles										
Chloroacetonitrile	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromoacetonitrile	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dichloroacetonitrile[d]	0.10	ND	0.1	0.1	0.3	0.3	0.3	0.2	0.2	0.1
Bromochloroacetonitrile[d]	0.10	ND	ND	ND	0.1	0.1	0.2	0.1	0.1	0.1
Dibromoacetonitrile[d]	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND
Trichloroacetonitrile[d]	0.10	ND	0.1	0.1	0.1	ND	ND	ND	ND	ND
Haloketones										
Chloropropanone	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloropropanone[d]	0.10	ND	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2
1,3-Dichloropropanone	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dibromopropanone	N/A	NR	NR	NR		NR	NR		NR	
1,1,1-Trichloropropanone[d]	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,3-Trichloropropanone	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND
1-Bromo-1,1-dichloropropanone	N/A	NR	NR	NR		NR	NR		NR	
1,1,1-Tribromopropanone	N/A	NR	NR	NR		NR	NR		NR	
1,1,3-Tribromopropanone	N/A	NR	NR	NR		NR	NR		NR	
1,1,3,3-Tetrachloropropanone	0.10	0.2	ND	ND	ND	ND	ND	ND	ND	ND
1,1,3,3-Tetrabromopropanone	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND
Haloacetaldehydes										
Dichloroacetaldehyde	0.16	ND	ND	0.5	0.6	0.6	0.6	0.8	0.9	1
Bromochloroacetaldehyde	0.10	ND	0.3	0.1	0.1	ND	ND	ND	ND	ND
Chloral hydrate[d]	0.10	ND	0.2	0.2	0.5	0.5	0.5	0.3	0.2	0.1
Tribromoacetaldehyde	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND
Halonitromethanes										
Bromonitromethane	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dichloronitromethane	N/A	NR	NR	NR		NR	NR		NR	
Dibromonitromethane	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloropicrin[d]	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND
Miscellaneous Compounds										
Methyl ethyl ketone	N/A	NR	NR	NR		NR	NR		NR	
Methyl *tertiary* butyl ether	0.16	0.3	ND	ND		ND	0.3		ND	
Benzyl chloride	N/A	NR	NR	NR	NR	NR	NR	NR	NR	NR

[k]Plant 9 sampled at (1) raw water, (2) primary conditioner, (3) basin #6 effluent, (4) filter influent, (5) finished water, distribution system (DS) at (6) average and at (7) maximum detention times, and SDS testing of finished water at (8) average and at (9) maximum detention times

[a]MRL = Minimum reporting level, which equals method detection limit (MDL)
or lowest calibration standard or concentration of blank
[b]Plant 10 sampled at train for Aldrich Purification units at (1) raw water, (2) filter influent, and (3) clearwell effluent;
at conventional treatment train at (4) raw water, (5) basins 4&5 effluent, (6) basins 1&2 effluent, (7) combined filter effluent, and (8) clearwell effluent;
and for combined treated waters at (9) finished water, distribution system (DS) at (10) average and at (11) maximum detention times,
and SDS testing of finished water at (12) average and at (13) maximum detention times
[c]ND = Not detected at or above MRL
[d]DBP in the Information Collection Rule (ICR) (note: some utilities collected data for all 9
haloacetic acids for the ICR, but monitoring for only 6 haloacetic acids was required)
[e]NR = Not reported, due to interference problem on gas chromatograph or to problem with quality assurance
[f]THM4 = Sum of 4 THMs (chloroform, bromodichloromethane, dibromochloromethane, bromoform)
[g]HAA5 = Sum of 5 haloacetic acids (monochloro-, monobromo-, dichloro-, dibromo-, trichloroacetic acid)
[h]HAA9 = Sum of 9 haloacetic acids
[i]DXAA = Sum of dihaloacetic acids (dichloro-, bromochloro-, dibromoacetic acid)
[j]TXAA = Sum of trihaloacetic acids (trichloro-, bromodichloro-, dibromochoro-, tribromoacetic acid)

Table 12. Additional target DBP results (µg/L) at Mississippi River WTPs (1/10/01)

1/10/01	Plant 9[a]					Plant 10[b]				
Compound	Raw	PC	PE	DS	SDS	Raw	B4&5	B1&2	FE	PE
Monochloroacetaldehyde	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.8	0.8	0.4
Dichloroacetaldehyde	0.0	0.0	0.9	0.9	0.9	0.0	4.6	3.9	3.7	3.6
Bromochloroacetaldehyde	0.0	0.0	0.0	0.0	0.0	0.0	0.8	2.0	0.7	1.3
3,3-Dichloropropenoic acid	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.4	0.6	0.8
Bromochloromethylacetate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2,2-Dichloroacetamide	0.0	0.0	0.0	0.0	0.0	0.0	2.1	1.5	1.9	1.7
TOX (µg/L as Cl^-)	7.4	58.7	64.4	55.7	61.5	13.7	222	252	203	237
Cyanoformaldehyde	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
5-Keto-1-hexanal	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
6-Hydroxy-2-hexanone	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Dimethylglyoxal	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
trans-2-Hexenal	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

[a]Plant 9 sampled at (1) raw water, (2) primary conditioner (PC), (3) finished water at plant effluent (PE), (4) distribution system (DS) at average detention time, and (5) SDS at maximum detection time.
[b]Plant 10 sampled at (1) raw water, (2) effluent of basins 4 and 5 (B4&5), (3) effluent of basins 1 and 2 (B1&2), (4) filter effluent (FE), and (5) PE.

Table 13. DBP results at plant 10 (4/9/01)

04/9/2001	MRL[a]	Aldrich[l]		Conventional[l]				Combined Plant[l]			
Compound	µg/L	Raw	Clearwell	Raw	Basins 4&5	Basins 1&2	Filt Eff	Finished	DS/Ave	SDS/Ave	SDS/Max
Halomethanes											
Chloromethane	0.5	ND[c]	ND	ND	ND		ND	ND	ND	ND	
Bromomethane	0.20	ND	ND	ND	ND		ND	ND	ND	ND	
Bromochloromethane	0.14	ND	ND	ND	ND		ND	ND	ND	ND	
Dibromomethane	0.11	ND	ND	ND	ND		ND	ND	ND	ND	
Chloroform[d]	0.1	ND	54	ND	40	22	46	50	45	42	54
Bromodichloromethane[d]	0.1	ND	15	ND	12	8	14	10	14	13	16
Dibromochloromethane[d]	0.1	ND	2	ND	2	0.8	2	1	2	2	2
Bromoform[d]	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
THM4[f]		ND	71	ND	54	31	62	61	61	57	72
Dichloroiodomethane	0.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromochloroiodomethane	0.20	ND	ND	ND	ND	NR	ND	ND	ND	ND	NR
Dibromoiodomethane	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chlorodiiodomethane	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromodiiodomethane	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Iodoform	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Carbon tetrachloride	0.06	ND	0.12	ND	ND		0.11	0.10	0.13	0.10	
Tribromochloromethane	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Haloacetic acids											
Monochloroacetic acid[d]	2		13		14	4.0	8.6	7.5	7.5	7.8	
Monobromoacetic acid[d]	1		ND		ND	ND	ND	ND	ND	ND	
Dichloroacetic acid[d]	1		33		36	23	21	27	25	28	
Bromochloroacetic acid[d]	1		5.6		6.5	3.7	3.0	5.3	4.8	5.0	
Dibromoacetic acid[d]	1		ND		ND	ND	ND	ND	ND	ND	
Trichloroacetic acid[d]	1		37		40	24	35	37	35	36	
Bromodichloroacetic acid	1		13		15	5.1	11	12	11	12	
Dibromochloroacetic acid	1		1.9		2.2	1.1	1.6	1.8	1.6	1.6	
Tribromoacetic acid	2		ND		ND	ND	ND	ND	ND	ND	
HAA5[g]			83		90	51	65	72	68	72	
HAA9[h]			104		114	61	80	91	85	90	
DXAA[i]			39		43	27	24	32	30	33	
TXAA[j]			52		57	30	48	51	48	50	
Haloacetonitriles											
Chloroacetonitrile	0.1	ND	0.5	ND	0.2	ND	0.2	0.1	0.3	0.2	0.3
Bromoacetonitrile	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dichloroacetonitrile[d]	0.10	ND	8	ND	7	3	3	3	4	4	4
Bromochloroacetonitrile[d]	0.1	ND	1	ND	1	0.5	0.5	0.4	0.7	0.7	1
Dibromoacetonitrile[d]	0.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Trichloroacetonitrile[d]	0.1	ND	0.4	ND	0.2	0.2	0.3	0.2	0.3	0.3	0.1
Haloketones											
Chloropropanone	0.5	ND	0.8	ND	0.5	ND	0.7	0.5	0.9	0.7	0.6
1,1-Dichloropropanone[d]	0.10	ND	1	ND	0.9	1	0.6	0.5	1	1	2
1,3-Dichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dibromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1-Trichloropropanone[d]	0.1	ND	6	ND	8	2	6	3	4	5	3
1,1,3-Trichloropropanone	0.1	ND	ND	ND	ND	0.3	ND	ND	ND	ND	ND
1-Bromo-1,1-dichloropropanone	0.1	ND	0.6	ND	0.8	0.4	0.5	0.3	0.4	0.4	ND
1,1,1-Tribromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,3-Tribromopropanone	0.14	ND	ND	ND	ND	0.1	ND	ND	ND	ND	ND
1,1,3,3-Tetrachloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1,3-Tetrachloropropanone	0.10	ND	ND	ND	0.1	0.1	ND	ND	ND	ND	ND
1,1,3,3-Tetrabromopropanone	0.6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Haloacetaldehydes											
Dichloroacetaldehyde	0.22	0.2	2	ND	2	2	1	1	2	2	3
Bromochloroacetaldehyde	0.1	ND	ND	ND	ND	0.4	ND	ND	ND	ND	0.2
Chloral hydrate[d]	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tribromoacetaldehyde	0.1	ND	ND	ND	ND	0.2	ND	ND	ND	ND	ND
Halonitromethanes											
Bromonitromethane	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dichloronitromethane	0.5	ND	0.4	ND	0.4	0.2	0.3	ND	0.3	0.3	0.1
Bromochloronitromethane	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dibromonitromethane	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloropicrin[d]	0.1	ND	2	ND	2	2	2	2	2	2	3
Miscellaneous Compounds											
Methyl ethyl ketone	1.9	ND	ND	ND	ND		ND	ND	ND	ND	
Methyl *tertiary* butyl ether	0.16	ND	ND	ND	ND		ND	ND	ND	ND	
Benzyl chloride	NA	ND	ND	ND	ND	NR[e]	ND	ND	ND	ND	NR

[l]Plant 10 sampled at train for Aldrich Purification units at (1) raw water and (2) clearwell effluent;
at conventional treatment train at (3) raw water, (4) basins 4&5 effluent, (5) basins 1&2 effluent, and (6) combined filter effluent;
and for combined treated waters at (7) finished water and (8) DS at average detention time,
and SDS testing of finished water at (9) average and at (10) maximum detention times

Table 14. DBP results at Plant 9 (4/9/01)

04/9/2001	MRL[a]	Plant 9[k]								
Compound	µg/L	Raw	1^{O} Cond	Basin #6	Filt Inf	Finished	DS/Ave	DS/Max	SDS/Ave	SDS/Max
Halomethanes										
Chloromethane	0.15	ND[c]	ND	ND		ND	ND		ND	
Bromomethane	0.20	ND	ND	ND		ND	ND		ND	
Bromochloromethane	0.14	ND	ND	ND		ND	ND		ND	
Dibromomethane	0.11	ND	ND	ND		ND	ND		ND	
Chloroform[d]	0.1	ND	6	5	6	6	5	6	7	7
Bromodichloromethane[d]	0.1	ND	1	1	2	2	3	3	3	2
Dibromochloromethane[d]	0.1	ND	0.1	ND	0.3	0.3	0.4	0.4	0.3	0.3
Bromoform[d]	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
THM4[f]		ND	7	6	8	8	8	9	10	9
Dichloroiodomethane	0.2	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromochloroiodomethane	0.20	ND	ND	ND	NR[e]	ND	ND	NR	ND	NR
Dibromoiodomethane	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chlorodiiodomethane	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromodiiodomethane	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND
Iodoform	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND
Carbon tetrachloride	0.06	ND	ND	ND		ND	ND		ND	
Tribromochloromethane	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Haloacetic acids										
Monochloroacetic acid[d]	2		ND	ND		ND	ND		ND	
Monobromoacetic acid[d]	1		ND	ND		ND	ND		ND	
Dichloroacetic acid[d]	1		11	12		15	14		18	
Bromochloroacetic acid[d]	1		1.4	1.3		2.9	2.6		2.4	
Dibromoacetic acid[d]	1		ND	ND		ND	ND		ND	
Trichloroacetic acid[d]	1		1.1	1.3		2.7	2.1		2.3	
Bromodichloroacetic acid	1		ND	ND		ND	ND		ND	
Dibromochloroacetic acid	1		ND	ND		ND	ND		ND	
Tribromoacetic acid	2		ND	ND		ND	ND		ND	
HAA5[g]			12	13		18	16		20	
HAA9[h]			14	15		21	19		23	
DXAA[i]			12	13		18	17		20	
TXAA[j]			1.1	1.3		2.7	2.1		2.3	
Haloacetonitriles										
Chloroacetonitrile	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromoacetonitrile	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dichloroacetonitrile[d]	0.10	ND	0.4	ND	0.3	0.3	0.1	0.1	0.1	0.1
Bromochloroacetonitrile[d]	0.1	ND	ND	ND	0.1	0.1	0.1	ND	ND	ND
Dibromoacetonitrile[d]	0.2	ND	ND	ND	ND	ND	ND	ND	ND	ND
Trichloroacetonitrile[d]	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Haloketones										
Chloropropanone	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloropropanone[d]	0.10	ND	0.7	0.3	0.4	0.4	0.2	0.2	0.1	0.1
1,3-Dichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dibromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1-Trichloropropanone[d]	0.1	ND	0.1	0.1	ND	0.4	ND	ND	ND	ND
1,1,3-Trichloropropanone	0.1	ND	ND	ND	ND	0.3	ND	ND	ND	ND
1-Bromo-1,1-dichloropropanone	0.1	ND	ND	ND	ND	0.1	ND	ND	ND	ND
1,1,1-Tribromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,3-Tribromopropanone	0.14	ND	ND	ND	ND	0.1	ND	ND	ND	ND
1,1,3,3-Tetrachloropropanone	0.1	ND	ND	0.1	ND	ND	ND	ND	ND	ND
1,1,1,3-Tetrachloropropanone	0.10	ND	ND	0.1	ND	0.1	ND	ND	ND	ND
1,1,3,3-Tetrabromopropanone	0.6	ND	ND	ND	ND	ND	ND	ND	ND	ND
Haloacetaldehydes										
Dichloroacetaldehyde	0.22	ND	1	2	2	3	2	2	2	2
Bromochloroacetaldehyde	0.1	ND	ND	ND	ND	0.2	ND	ND	ND	ND
Chloral hydrate[d]	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tribromoacetaldehyde	0.1	ND	ND	0.1	ND	0.4	ND	ND	ND	ND
Halonitromethanes										
Bromonitromethane	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dichloronitromethane	0.5	ND	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2
Bromochloronitromethane	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dibromonitromethane	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloropicrin[d]	0.1	ND	0.1	ND	0.2	0.2	0.1	0.1	0.1	ND
Miscellaneous Compounds										
Methyl ethyl ketone	1.9	ND	ND	ND		ND	ND		ND	
Methyl *tertiary* butyl ether	0.16	ND	ND	ND		ND	ND		ND	
Benzyl chloride	NA	ND	ND	ND	NR	ND	ND	NR	ND	NR

Table 15. Occurrence of other DBPs[a] at Mississippi River WTPs: finished waters at plant effluents

Compound	Plant 10		Plant 9
	4/9/01	2/25/02	8/27/01
<u>Halomethanes</u>			
Bromodichloromethane[b]	x	x	x
Dibromochloromethane	x	x	x
Bromoform	x	-	x
Dichloroiodomethane	x	x	x
Bromochloroiodomethane	x	x	x
<u>Haloacids</u>			
Dichloroacetic acid	x	x	x
Bromochloroacetic acid	x	x	x
Dibromoacetic acid	-	-	x
Bromodichloroacetic acid	x	-	-
Trichloroacetic acid	x	x	-
3,4,4-Trichloro-3-butenoic acid	x	-	-
cis-2-Bromo-3-methylbutenedioic acid	x	-	-
<u>Haloacetonitriles</u>			
Dichloroacetonitrile	x	x	x
Bromochloroacetonitrile	x	x	x
Dibromoacetonitrile	x	x	x
Dibromochloroacetonitrile	x	-	-
<u>Haloaldehydes</u>			
2-Bromo-2-methylpropanal	x	x	x
<u>Haloketones</u>			
1,1-Dichloropropanone	x	x	-
1-Bromo-1-chloropropanone	x	x	-
1,1,1-Trichloropropanone	x	-	-
1-Bromo-1,1-dichloropropanone	x	-	-
1,1,3-Tribromo-3-chloropropanone	-	-	x
1,1,3,3-Tetrabromopropanone	-	-	x
Pentachloropropanone	x	-	x
Hexachloropropanone	x	-	-
<u>Halonitromethanes</u>			
Dichloronitromethane	x	x	-
Bromochloronitromethane	x	-	-
Bromodichloronitromethane	x	-	-
<u>Halofuranones</u>			
Ox-MX	x	-	-
<u>Miscellaneous Halogenated DBPs</u>			
1,2-Dichloroethylbenzene	x	-	-
Dichlorophenol	-	-	x
Tetrachlorocyclopentadiene	x	-	-
Hexachlorocyclopentadiene	x	-	-
Bromopentachlorocyclopentadiene	x	-	-
<u>Non-halogenated DBPs</u>			
Glyoxal	x	-	-
4-Methylpentanoic acid	-	-	x
Dodecanoic acid	x	-	-

[a]DBPs detected by broadscreen gas chromatography/mass spectrometry (GC/MS) technique.
[b]Compounds listed in italics were confirmed through the analysis of authentic standards; haloacids and non-halogenated carboxylic acids identified as their methyl esters.

Table 16. DBP results at plant 10 (9/5/01)

09/05/2001	MRL[a]	Aldrich[l]		Conventional[l]				Combined Plant[l]			
Compound	µg/L	Raw	Clearwell	Raw	Basins 4&5	Basins 1&2	Filt Eff	Finished	DS/Ave	SDS/Ave	SDS/Max
Halomethanes											
Chloromethane	0.2	ND[c]	ND	ND	ND		ND	ND	ND	ND	
Bromomethane	0.2	ND	ND	ND	ND		ND	ND	ND	ND	
Bromochloromethane	0.5	ND	ND	ND	ND		ND	ND	ND	ND	
Dibromomethane	0.5	ND	ND	ND	ND		ND	ND	ND	ND	
Chloroform[d]	0.1	ND	100	0.2	100	120	110	120	150	120	270
Bromodichloromethane[d]	0.1	ND	40	ND	40	50	40	40	50	30	60
Dibromochloromethane[d]	0.1	ND	4	ND	4	4	4	4	6	4	9
Bromoform[d]	0.1	ND	ND	ND	ND	ND	ND	ND	ND	0.2	0.2
THM4[f]	0	ND	144	ND	144	174	154	164	206	154	339
Dichloroiodomethane	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromochloroiodomethane	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dibromoiodomethane	0.52	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chlorodiiodomethane	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromodiiodomethane	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Iodoform	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Carbon tetrachloride	0.2	ND	0.3	ND	ND		ND	ND	ND	ND	
Tribromochloromethane	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Haloacetic acids											
Monochloroacetic acid[d]	2		9.0		5.9	6.5	ND	2.4	5.2	ND	
Monobromoacetic acid[d]	1		1.2		1.1	1.2	ND	ND	1.0	ND	
Dichloroacetic acid[d]	1		64		51	53	13	24	41	26	
Bromochloroacetic acid[d]	1		9.4		9.0	9.0	2.4	4.4	6.1	5.4	
Dibromoacetic acid[d]	1		ND		1.0	1.0	ND	ND	ND	ND	
Trichloroacetic acid[d]	1		91		90	85	73	80	87	82	
Bromodichloroacetic acid	1		19		16	18	16	17	18	18	
Dibromochloroacetic acid	1		1.2		1.9	1.1	1.1	1.7	1.2	1.8	
Tribromoacetic acid	2		3.3		2.7	2.5	ND	ND	2.4	ND	
HAA5[g]			165		149	147	86	106	134	108	
HAA9[h]			198		179	177	106	130	162	133	
DXAA[i]			73		61	63	15	28	47	31	
TXAA[j]			115		111	107	90	99	109	102	
Haloacetonitriles											
Chloroacetonitrile	0.1	ND	1	ND	0.6	0.8	0.6	0.7	0.9	1	0.9
Bromoacetonitrile	0.1	ND	ND	ND	ND	ND	ND	ND	ND	0.2	0.3
Dichloroacetonitrile[d]	0.1	ND	22	ND	21	23	9	12	19	16	18
Bromochloroacetonitrile[d]	0.1	ND	1	ND	2	2	0.6	1	2	1	1
Dibromoacetonitrile[d]	0.1	ND	0.2	ND	0.4	ND	ND	ND	0.3	ND	0.2
Trichloroacetonitrile[d]	0.1	ND	ND	ND	0.2	0.2	0.1	0.1	ND	ND	ND
Bromodichloroacetonitrile	0.5			ND	0.8		ND	ND			
Dibromochloroacetonitrile	0.5			ND	ND		ND	ND			
Tribromoacetonitrile	0.91			ND	ND		ND	ND			
Haloketones											
Chloropropanone	0.1	ND	0.5	ND	0.7	0.7	0.8	0.8	1	0.7	0.8
1,1-Dichloropropanone[d]	0.10	ND	0.5	ND	0.6	1	0.9	0.8	0.4	0.5	0.2
1,3-Dichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dibromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1-Trichloropropanone[d]	0.1	ND	7	ND	9	8	6	7	7	7	0.8
1,1,3-Trichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1-Bromo-1,1-dichloropropanone	0.1	ND	ND	ND	0.3	ND	ND	ND	ND	ND	ND
1,1,1-Tribromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND	NR[e]	NR
1,1,3-Tribromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,3,3-Tetrachloropropanone	0.1	ND	0.2	ND	0.2	1	ND	ND	0.3	0.3	0.1
1,1,1,3-Tetrachloropropanone	0.10	ND	0.3	ND	0.3	0.8	0.5	0.4	0.3	0.4	0.2
1,1,3,3-Tetrabromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Table 16 (continued)

09/05/2001	MRL[a]	Aldrich[l]		Conventional[l]				Combined Plant[l]			
Compound	µg/L	Raw	Clearwell	Raw	Basins 4&5	Basins 1&2	Filt Eff	Finished	DS/Ave	SDS/Ave	SDS/Max
Haloacetaldehydes											
Dichloroacetaldehyde	0.221	ND	4	ND	4	7	3	4	3	4	2
Bromochloroacetaldehyde	0.5	ND	2	ND	2	2	0.7	ND	ND	1	ND
Chloral hydrate[d]	0.1	ND	29	2	22	22	16	16	26	28	62
Tribromoacetaldehyde	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Halonitromethanes											
Bromonitromethane	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dichloronitromethane	0.1	ND	0.3	ND	0.4	0.2	ND	ND	0.2	0.2	0.3
Bromochloronitromethane	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dibromonitromethane	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloropicrin[d]	0.1	ND	2	ND	1	0.8	0.8	0.7	1	0.7	1
Bromodichloronitromethane	0.5			ND	0.9		0.5	0.6			
Dibromochloronitromethane	0.505			ND	ND		ND	ND			
Bromopicrin	2.1			ND	ND		ND	ND			
Miscellaneous Compounds											
Methyl ethyl ketone	0.5	ND	ND	ND	0.6		0.6	0.6	0.6	0.7	
Methyl *tertiary* butyl ether	0.2	1.6	1.0	1.3	1.0		1.0	0.9	0.8	1.0	
Benzyl chloride	0.5	ND	ND	ND	ND	NR	ND	ND	ND	ND	NR
1,1,2,2-Tetrabromo-2-chloroethane	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Table 17. DBP results at plant 9 (8/27/01)

08/27/2001	MRL[a]	Plant 9[k]								
Compound	µg/L	Raw	1^{O} Cond	Basin #6	Filt Inf	Finished	DS/Ave	DS/Max	SDS/Ave	SDS/Max
Halomethanes										
Chloromethane	0.2	ND[c]	ND	ND		ND	ND		ND	
Bromomethane	0.2	ND	ND	ND		ND	ND		ND	
Bromochloromethane	0.5	ND	ND	ND		ND	ND		ND	
Dibromomethane	0.5	ND	ND	ND		ND	ND		ND	
Chloroform[d]	0.1	ND	4	4	5	4	6	8	5	5
Bromodichloromethane[d]	0.1	ND	2	2	2	2	3	2	3	2
Dibromochloromethane[d]	0.1	ND	0.3	0.5	0.9	1	1	0.7	1	1
Bromoform[d]	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
THM4[f]		ND	6	7	8	7	10	11	9	8
Dichloroiodomethane	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromochloroiodomethane	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dibromoiodomethane	0.52	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chlorodiiodomethane	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromodiiodomethane	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND
Iodoform	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Carbon tetrachloride	0.2	ND	ND	ND		ND	ND		ND	
Tribromochloromethane	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND
Haloacetic acids										
Monochloroacetic acid[d]	2		ND	ND		ND	ND		ND	
Monobromoacetic acid[d]	1		ND	ND		ND	ND		ND	
Dichloroacetic acid[d]	1		8.4	11		15	18		17	
Bromochloroacetic acid[d]	1		1.7	1.6		2.9	3.5		3.7	
Dibromoacetic acid[d]	1		ND	ND		1.1	1.3		ND	
Trichloroacetic acid[d]	1		1.3	1.1		1.3	1.6		1.2	
Bromodichloroacetic acid	1		ND	ND		1.0	1.0		ND	
Dibromochloroacetic acid	1		ND	ND		ND	ND		ND	
Tribromoacetic acid	2		ND	ND		ND	ND		ND	
HAA5[g]			9.7	12		17	21		18	
HAA9[h]			11	14		21	25		22	
DXAA[i]			10	13		19	23		21	
TXAA[j]			1.3	1.1		2.3	2.6		1.2	
Haloacetonitriles										
Chloroacetonitrile	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromoacetonitrile	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dichloroacetonitrile[d]	0.1	ND	0.5	ND	ND	ND	ND	ND	ND	ND
Bromochloroacetonitrile[d]	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dibromoacetonitrile[d]	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Trichloroacetonitrile[d]	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromodichloroacetonitrile	0.5	ND	ND			ND				ND
Dibromochloroacetonitrile	0.5	ND	ND			ND				ND
Tribromoacetonitrile	0.91	ND	ND			ND				ND
Haloketones										
Chloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND	0.1	ND
1,1-Dichloropropanone[d]	0.10	ND	0.7	ND	ND	ND	ND	ND	ND	ND
1,3-Dichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dibromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1-Trichloropropanone[d]	0.1	ND	0.3	ND	ND	ND	ND	ND	ND	ND
1,1,3-Trichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
1-Bromo-1,1-dichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1-Tribromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,3-Tribromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,3,3-Tetrachloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1,3-Tetrachloropropanone	0.10	ND	ND	0.5	0.2	0.2	ND	ND	ND	0.4
1,1,3,3-Tetrabromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND

Table 17 (continued)

08/27/2001	MRL[a]	Plant 9[k]								
Compound	µg/L	Raw	1^{O} Cond	Basin #6	Filt Inf	Finished	DS/Ave	DS/Max	SDS/Ave	SDS/Max
<u>Haloacetaldehydes</u>										
Dichloroacetaldehyde	0.221	ND	1	1	0.6	1	0.9	ND	0.2	0.9
Bromochloroacetaldehyde	0.5	ND	ND	ND	ND	ND	ND	ND	ND	0.8
Chloral hydrate[d]	0.1	ND	0.5	0.5	ND	0.3	0.2	ND	ND	0.6
Tribromoacetaldehyde	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
<u>Halonitromethanes</u>										
Bromonitromethane	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dichloronitromethane	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromochloronitromethane	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dibromonitromethane	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloropicrin[d]	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromodichloronitromethane	0.5	ND	ND			ND				0.6
Dibromochloronitromethane	0.51	ND	ND			0.6				ND
Bromopicrin	2.1	ND	ND			ND				ND
<u>Miscellaneous Compounds</u>										
Methyl ethyl ketone	0.5	ND	ND	ND		1	0.5		0.5	
Methyl *tertiary* butyl ether	0.2	0.2	ND	ND		ND	ND		ND	
Benzyl chloride	0.5	ND	ND	ND	NR[e]	ND	ND	NR	ND	NR
1,1,2,2-Tetrabromo-2-chloroethane	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND

Table 18. DBP results at plant 10 (11/26/01)

11/26/2001	MRL[a]	Aldrich[l]		Conventional[l]				Combined Plant[l]			
Compound	µg/L	Raw	Clearwell	Raw	Basins 4&5	Basins 1&2	Filt Eff	Finished	DS/Ave	SDS/Ave	SDS/Max
Halomethanes											
Chloromethane	0.2	ND[c]	ND	ND	ND		ND	ND	ND	ND	
Bromomethane	0.2	ND	ND	ND	ND		ND	ND	ND	ND	
Bromochloromethane	0.5	ND	ND	ND	ND		ND	ND	ND	ND	
Dibromomethane	0.5	ND	ND	ND	ND		ND	ND	ND	ND	
Chloroform[d]	0.2	ND	13	ND	10	NS[m]	12	12	14	12	NA[n]
Bromodichloromethane[d]	0.1	ND	5	ND	4	NS	4	4	5	5	NA
Dibromochloromethane[d]	0.1	ND	0.6	ND	0.4	NS	0.4	0.5	0.6	0.6	NA
Bromoform[d]	0.11	ND	ND	ND	ND	NS	ND	ND	ND	ND	NA
THM4[f]	0	ND	19	ND	14	NS	16	17	20	18	NA
Dichloroiodomethane	0.5	ND	1	ND	1	NS	0.9	1	1	1	NA
Bromochloroiodomethane	0.5	ND	ND	ND	ND	NS	ND	ND	ND	ND	NA
Dibromoiodomethane	0.52	ND	ND	ND	ND	NS	ND	ND	ND	ND	NA
Chlorodiiodomethane	0.1	ND	ND	ND	ND	NS	ND	ND	ND	ND	NA
Bromodiiodomethane	0.5	ND	ND	ND	ND	NS	ND	ND	ND	ND	NA
Iodoform	2	ND	ND	ND	ND	NS	ND	ND	ND	ND	NA
Carbon tetrachloride	0.2	ND	0.3	ND	ND		ND	ND	ND	ND	
Tribromochloromethane	0.5	ND	ND	ND	ND	NS	ND	ND	ND	ND	NA
Haloacetic acids											
Monochloroacetic acid[d]	2		ND		2.8	NS	ND	ND	3.5	ND	
Monobromoacetic acid[d]	1		1.2		ND	NS	1.0	ND	1.3	1.2	
Dichloroacetic acid[d]	1		16		14	NS	6.2	11	13	11	
Bromochloroacetic acid[d]	1		2.3		2.0	NS	ND	2.4	2.2	2.4	
Dibromoacetic acid[d]	1		ND		ND	NS	ND	ND	ND	ND	
Trichloroacetic acid[d]	1		6.5		5.4	NS	4.4	6.1	6.0	6.1	
Bromodichloroacetic acid	1		1.1		ND	NS	ND	1.0	ND	1.0	
Dibromochloroacetic acid	1		ND		ND	NS	ND	ND	ND	ND	
Tribromoacetic acid	2		ND		ND	NS	ND	ND	ND	ND	
HAA5[g]			24		22	NS	12	17	24	18	
HAA9[h]			27		24	NS	12	21	26	22	
DXAA[i]			18		16	NS	6.2	13	15	13	
TXAA[j]			7.6		5.4	NS	4.4	7.1	6.0	7.1	
Haloacetonitriles											
Chloroacetonitrile	0.1	ND	ND	ND	ND	NS	ND	ND	ND	ND	NA
Bromoacetonitrile	0.1	ND	ND	ND	ND	NS	ND	ND	ND	ND	NA
Dichloroacetonitrile[d]	0.1	ND	2	ND	1	NS	0.7	1	2	1	NA
Bromochloroacetonitrile[d]	0.1	ND	ND	ND	ND	NS	ND	ND	0.3	0.2	NA
Dibromoacetonitrile[d]	0.14	ND	ND	ND	ND	NS	ND	ND	ND	ND	NA
Trichloroacetonitrile[d]	0.1	ND	ND	ND	ND	NS	ND	ND	ND	ND	NA
Bromodichloroacetonitrile	0.5			ND	ND		ND	ND			
Dibromochloroacetonitrile	0.5			ND	ND		ND	ND			
Tribromoacetonitrile	0.5			ND	ND		ND	ND			
Haloketones											
Chloropropanone	0.1	ND	ND	ND	ND	NS	ND	ND	ND	ND	NA
1,1-Dichloropropanone[d]	0.10	ND	1	ND	1	NS	0.6	0.8	1	0.8	NA
1,3-Dichloropropanone	0.1	ND	ND	ND	ND	NS	ND	ND	ND	ND	NA
1,1-Dibromopropanone	0.1	ND	ND	ND	ND	NS	ND	ND	ND	ND	NA
1,1,1-Trichloropropanone[d]	0.1	ND	1	ND	1	NS	0.8	0.9	1	0.9	NA
1,1,3-Trichloropropanone	0.1	ND	ND	ND	ND	NS	ND	ND	ND	ND	NA
1-Bromo-1,1-dichloropropanone	0.1	ND	ND	ND	ND	NS	ND	ND	ND	ND	NA
1,1,1-Tribromopropanone	2.5	NR	ND	ND	ND	NS	ND	ND	ND	ND	NA
1,1,3-Tribromopropanone	0.14	ND	ND	ND	ND	NS	ND	ND	ND	ND	NA
1,1,3,3-Tetrachloropropanone	0.10	ND	ND	ND	ND	NS	ND	ND	ND	ND	NA
1,1,1,3-Tetrachloropropanone	0.10	ND	ND	ND	ND	NS	ND	ND	ND	ND	NA
1,1,3,3-Tetrabromopropanone	0.5	ND	ND	ND	ND	NS	ND	ND	ND	ND	NA

Table 18 (continued)

11/26/2001	MRL[a]	Aldrich[l]		Conventional[l]				Combined Plant[l]			
Compound	µg/L	Raw	Clearwell	Raw	Basins 4&5	Basins 1&2	Filt Eff	Finished	DS/Ave	SDS/Ave	SDS/Max
Haloacetaldehydes											
Dichloroacetaldehyde	1.1	ND	4	ND	2	NS	2	2	3	2	NA
Bromochloroacetaldehyde	0.5	ND	0.9	ND	0.6	NS	ND	0.6	1	1	NA
Chloral hydrate[d]	0.1	ND	2	ND	1	NS	1	1	2	1	NA
Tribromoacetaldehyde	0.1	ND	ND	ND	ND	NS	ND	ND	ND	ND	NA
Halonitromethanes											
Bromonitromethane	0.1	ND	ND	ND	ND	NS	ND	ND	ND	ND	NA
Dichloronitromethane	0.1	ND	ND	ND	ND	NS	ND	ND	0.1	0.1	NA
Bromochloronitromethane	0.1	ND	ND	ND	ND	NS	ND	ND	ND	ND	NA
Dibromonitromethane	0.10	ND	ND	ND	ND	NS	ND	ND	ND	ND	NA
Chloropicrin[d]	0.1	ND	0.8	ND	0.4	NS	0.5	0.5	0.7	0.6	NA
Bromodichloronitromethane	0.5			ND	ND		ND	ND			
Dibromochloronitromethane	0.5			ND	ND		ND	ND			
Bromopicrin	0.90			ND	ND		ND	ND			
Miscellaneous Compounds											
Methyl ethyl ketone	0.5	ND	ND	ND	ND		ND	ND	ND	ND	
Methyl *tertiary* butyl ether	0.2	ND	ND	ND	ND		ND	ND	ND	ND	
Benzyl chloride	0.25	NR	ND	ND	ND	NS	ND	ND	ND	ND	NA
1,1,2,2-Tetrabromo-2-chloroethane	0.5	ND	ND	ND	ND	NS	ND	ND	ND	ND	NA

[m]NS = Not sampled

[n]NA = Not available

Table 19. DBP results at plant 9 (11/26/01)

11/26/2001	MRL[a]	Plant 9[k]								
Compound	µg/L	Raw	1^{O} Cond	Basin #6	Filt Inf	Finished	DS/Ave	DS/Max	SDS/Ave	SDS/Max
Halomethanes										
Chloromethane	0.2	ND[c]	ND	ND		ND	ND		ND	
Bromomethane	0.2	ND	ND	ND		ND	0.2		ND	
Bromochloromethane	0.5	ND	ND	ND		ND	ND		ND	
Dibromomethane	0.5	ND	ND	ND		ND	ND		ND	
Chloroform[d]	0.2	ND	4	2	2	3	4	6	2	NA[n]
Bromodichloromethane[d]	0.1	ND	2	2	2	3	5	6	2	NA
Dibromochloromethane[d]	0.1	ND	0.9	0.9	2	2	4	4	2	NA
Bromoform[d]	0.11	ND	ND	0.1	0.4	0.4	1	1	0.5	NA
THM4[f]		ND	7	5	6	8	14	17	7	NA
Dichloroiodomethane	0.5	ND	<0.5[o]	<0.5	NR[e]	1	2	NR	1	NA
Bromochloroiodomethane	0.5	ND	ND	ND	ND	ND	<0.5	ND	ND	NA
Dibromoiodomethane	0.52	ND	ND	ND	ND	ND	ND	ND	ND	NA
Chlorodiiodomethane	0.1	ND	ND	ND	ND	ND	ND	ND	ND	NA
Bromodiiodomethane	0.5	ND	ND	ND	ND	ND	ND	ND	ND	NA
Iodoform	2	ND	ND	ND	ND	ND	ND	ND	ND	NA
Carbon tetrachloride	0.2	ND	ND	ND		ND	ND		ND	
Tribromochloromethane	0.5	ND	ND	ND	ND	ND	ND	ND	ND	NA
Haloacetic acids										
Monochloroacetic acid[d]	2		ND	ND		ND	2.4		2.9	
Monobromoacetic acid[d]	1		1.2	1.3		1.2	1.2		ND	
Dichloroacetic acid[d]	1		5.1	5.0		6.2	7.9		6.2	
Bromochloroacetic acid[d]	1		1.8	2.2		2.5	4.2		3.4	
Dibromoacetic acid[d]	1		1.0	1.3		2.1	3.0		1.9	
Trichloroacetic acid[d]	1		ND	ND		ND	ND		ND	
Bromodichloroacetic acid	1		ND	ND		ND	ND		ND	
Dibromochloroacetic acid	1		ND	ND		ND	ND		ND	
Tribromoacetic acid	2		ND	ND		ND	ND		ND	
HAA5[g]			7.3	7.6		9.5	15		11	
HAA9[h]			9.1	9.8		12	19		14	
DXAA[i]			7.9	8.5		11	15		12	
TXAA[j]			ND	ND		ND	ND		ND	
Haloacetonitriles										
Chloroacetonitrile	0.1	ND	ND	ND	ND	ND	ND	ND	ND	NA
Bromoacetonitrile	0.1	ND	ND	ND	ND	ND	ND	ND	NA	NA
Dichloroacetonitrile[d]	0.10	ND	ND	ND	ND	ND	ND	ND	NA	NA
Bromochloroacetonitrile[d]	0.1	ND	ND	ND	ND	ND	ND	ND	ND	NA
Dibromoacetonitrile[d]	0.14	ND	ND	ND	ND	ND	ND	ND	ND	NA
Trichloroacetonitrile[d]	0.1	ND	ND	ND	ND	ND	ND	ND	NA	NA
Bromodichloroacetonitrile	0.5	ND	ND			ND				ND
Dibromochloroacetonitrile	0.5	ND	ND			ND				ND
Tribromoacetonitrile	0.5	ND	ND			ND				ND
Haloketones										
Chloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND	NA
1,1-Dichloropropanone[d]	0.10	ND	0.1	ND	ND	ND	ND	ND	ND	NA
1,3-Dichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND	NA	NA
1,1-Dibromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND	NA	NA
1,1,1-Trichloropropanone[d]	0.1	ND	ND	ND	ND	ND	ND	ND	ND	NA
1,1,3-Trichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND	NA	NA
1-Bromo-1,1-dichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND	NA
1,1,1-Tribromopropanone	2.5	ND	ND	ND	NR	ND	ND	NR	ND	NA
1,1,3-Tribromopropanone	0.14	ND	ND	ND	ND	ND	ND	ND	NA	NA
1,1,3,3-Tetrachloropropanone	0.10	ND	ND	ND	ND	ND	ND	ND	NA	NA
1,1,1,3-Tetrachloropropanone	0.10	ND	ND	ND	ND	ND	ND	ND	NA	NA
1,1,3,3-Tetrabromopropanone	0.5	ND	ND	ND	ND	ND	ND	ND	NA	NA

Table 19 (continued)

11/26/2001	MRL[a]	Plant 9[k]								
Compound	µg/L	Raw	1^{O} Cond	Basin #6	Filt Inf	Finished	DS/Ave	DS/Max	SDS/Ave	SDS/Max
Haloacetaldehydes										
Dichloroacetaldehyde	1.1	ND	1	2	2	2	3	2	NA	NA
Bromochloroacetaldehyde	0.5	ND	ND	ND	ND	ND	ND	ND	NA	NA
Chloral hydrate[d]	0.1	ND	0.3	ND	0.1	ND	0.6	0.4	NA	NA
Tribromoacetaldehyde	0.1	ND	ND	ND	ND	ND	ND	ND	NA	NA
Halonitromethanes										
Bromonitromethane	0.1	ND	ND	ND	ND	ND	ND	ND	NA	NA
Dichloronitromethane	0.1	ND	ND	ND	ND	ND	0.2	0.1	ND	NA
Bromochloronitromethane	0.1	ND	ND	ND	ND	ND	ND	ND	ND	NA
Dibromonitromethane	0.10	ND	ND	ND	ND	ND	ND	ND	ND	NA
Chloropicrin[d]	0.1	ND	ND	ND	ND	ND	0.3	ND	NA	NA
Bromodichloronitromethane	0.5	ND	ND			0.7				0.7
Dibromochloronitromethane	0.5	ND	ND			1				ND
Bromopicrin	0.90	ND	ND			2				3
Miscellaneous Compounds										
Methyl ethyl ketone	0.5	1	ND	ND		ND	0.8		1	
Methyl *tertiary* butyl ether	0.2	ND	ND	ND		ND	ND		ND	
Benzyl chloride	0.25	ND	ND	ND	NR	ND	ND	NR	ND	NA
1,1,2,2-Tetrabromo-2-chloroethane	0.5	ND	ND	ND	ND	ND	ND	ND	ND	NA

[o]<0.5 = Less than MRL (0.5 µg/L)

Table 20. Additional target DBP results (μg/L) at Mississippi River WTPs (11/26/01)

11/26/01	Plant 9[c]					Plant 10[d]					
Compound	Soft.	PC	PE	DS	SDS	Raw	B4&5	B1&2	FE	PE	SDS
Monochloroacetaldehyde	0.0	0.4	0.0		0.0	0.0	0.0		0.0	0.0	
Dichloroacetaldehyde	0.0	4.6	5.0		1.1	0.0	4.6		2.5	2.3	
Bromochloroacetaldehyde	0.0	0.2	0.2		0.0	0.0	0.6		0.4	0.80	
3,3-Dichloropropenoic acid	0.0	0.0	0.0	0.0	0.0	0.0	0.4		0.4	0.4	
Bromochloromethylacetate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NA	0.0	0.0	0.0
TOX (μg/L as Cl^-)	2.8	82.7	66.4	99.2		29.5	207		144	175	
Cyanoformaldehyde	<0.1	<0.1	<0.1	NA	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
5-Keto-1-hexanal	<0.1	<0.1	<0.1	NA	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
6-Hydroxy-2-hexanone	<0.1	<0.1	<0.1	NA	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Dimethylglyoxal	0.3	0.3	0.2	NA	0.4	<0.1	0.7	<0.1	0.1	0.3	<0.1
trans-2-Hexenal	<0.1	<0.1	<0.1	NA	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

[c]Plant 9 sampled at softened water rather than at raw water.
[d]Plant 10 also sampled at SDS at maximum detection time.

Table 21. Halogenated furanone results (μg/L) at Mississippi River WTPs (11/26/01)

11/26/01	Plant 9[c]					Plant 10[e]			
Compound	Soft.	PC	PE	DS	SDS	Raw	B4&5	FE	PE
BMX-1	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.03	<0.02	<0.02
BEMX-1	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
BMX-2	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
BEMX-2	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
BMX-3	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.02	<0.02	<0.02
BEMX-3	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
MX	<0.02	<0.02	<0.02 (0.018)	<0.02 (0.013)	NA	<0.02	0.40	<0.02	0.06
EMX	<0.02	<0.02	<0.02	<0.02	NA	<0.02	<0.02	<0.02	<0.02
ZMX	<0.02 (0.01)	0.03	0.02	<0.02	NA	<0.02	<0.02	0.04	<0.02
Ox-MX	<0.02	<0.02	<0.02	<0.02	NA	<0.02	<0.02	<0.02	<0.02
Mucochloric acid (ring)	<0.02	0.03	0.08	0.07	NA	<0.02	<0.02	0.03	<0.02
Mucochloric acid (open)	<0.02 (0.01)	0.03	0.08	0.10	NA	<0.02	<0.02	0.03	<0.02

[e]Plant 10 sampled at (1) raw water, (2) B4&5, (3) FE, and (4) PE.

Table 22. DBP results at plant 10 (2/25/02)

02/25/2002	MRL[a]	Aldrich[l]		Conventional[l]				Combined Plant[l]			
Compound	µg/L	Raw	Clearwell	Raw	Basins 4&5	Basins 1&2	Filt Eff	Finished	DS/Ave	SDS/Ave	SDS/Max
Halomethanes											
Chloromethane	0.2	ND[c]	ND	ND	ND		ND	ND	ND	ND	
Bromomethane	0.2	ND	ND	ND	ND		ND	ND	ND	ND	
Bromochloromethane	0.5	ND	ND	ND	ND		ND	ND	ND	ND	
Dibromomethane	0.5	ND	ND	ND	ND		ND	ND	ND	ND	
Chloroform[d]	0.2	ND	8	ND	5	NR[e]	8	10	11	11	NR
Bromodichloromethane[d]	0.2	ND	3	ND	2	NR	3	4	5	5	4
Dibromochloromethane[d]	0.2	ND	0.5	ND	0.4	NR	0.4	0.6	0.7	0.7	0.7
Bromoform[d]	0.2	ND	<0.2[p]	ND	<0.2	ND	<0.2	<0.2	<0.2	<0.2	ND
THM4[f]		ND	12	ND	8	NR	12	15	17	17	NR
Dichloroiodomethane	0.5	ND	<0.5	ND	ND	NR	<0.5	<0.5	<0.5	<0.5	NR
Bromochloroiodomethane	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dibromoiodomethane	0.5	ND	ND	ND	ND	NR	ND	ND	ND	ND	NR
Chlorodiiodomethane	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromodiiodomethane	0.52	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Iodoform	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Carbon tetrachloride	0.2	ND	ND	ND	ND		ND	ND	ND	ND	
Tribromochloromethane	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Haloacetic acids											
Monochloroacetic acid[d]	2		2.5		2.9	NR	ND	ND	ND	ND	
Monobromoacetic acid[d]	1		ND		ND	NR	ND	ND	ND	ND	
Dichloroacetic acid[d]	1		12		13	NR	14	14	14	12	
Bromochloroacetic acid[d]	1		2.2		2.2	NR	2.7	2.7	2.7	2.0	
Dibromoacetic acid[d]	1		ND		ND	NR	ND	ND	ND	ND	
Trichloroacetic acid[d]	1		6.2		6.9	NR	11	11	11	6.9	
Bromodichloroacetic acid	1		1.3		1.4	NR	2.6	2.6	2.5	1.4	
Dibromochloroacetic acid	1		3.0		4.0	NR	2.9	2.5	2.7	1.4	
Tribromoacetic acid	2		ND		ND	NR	ND	ND	ND	ND	
HAA5[g]			21		23	NR	25	25	25	19	
HAA9[h]			27		30	NR	33	33	33	24	
DXAA[i]			14		15	NR	17	17	17	14	
TXAA[j]			11		12	NR	17	16	16	9.7	
Haloacetonitriles											
Chloroacetonitrile	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromoacetonitrile	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dichloroacetonitrile[d]	0.2	ND	0.4	ND	0.5	NR	0.4	0.5	0.4	0.4	NR
Bromochloroacetonitrile[d]	0.2	NR	ND	ND	ND	NR	ND	ND	ND	ND	NR
Dibromoacetonitrile[d]	1.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Trichloroacetonitrile[d]	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromodichloroacetonitrile	0.5			ND	ND		ND	ND			
Dibromochloroacetonitrile	0.5			ND	ND		ND	ND			
Tribromoacetonitrile	0.955			ND	ND		ND	ND			
Haloketones											
Chloropropanone	0.5	ND	ND	ND	ND	NR	ND	ND	ND	ND	NR
1,1-Dichloropropanone[d]	1.0	ND	<1[q]	ND	<1	NR	ND	<1	<1	<1	NR
1,3-Dichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dibromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1-Trichloropropanone[d]	0.5	NR	0.9	ND	0.6	NR	0.5	0.9	1	0.7	NR
1,1,3-Trichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1-Bromo-1,1-dichloropropanone	0.1	ND	ND	ND	ND	0.1	ND	ND	ND	<1	ND
1,1,1-Tribromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,3-Tribromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,3,3-Tetrachloropropanone	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1,3-Tetrachloropropanone	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,3,3-Tetrabromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Table 22 (continued)

02/25/2002	MRL[a]	Aldrich[l]		Conventional[l]				Combined Plant[l]			
Compound	µg/L	Raw	Clearwell	Raw	Basins 4&5	Basins 1&2	Filt Eff	Finished	DS/Ave	SDS/Ave	SDS/Max
<u>Haloacetaldehydes</u>											
Dichloroacetaldehyde	0.98	ND	2	ND	2	3	2	2	2	4	3
Bromochloroacetaldehyde	0.5	ND	0.5	ND	ND	0.6	ND	ND	0.7	1	0.9
Chloral hydrate[d]	0.1	ND	0.8	0.2	0.7	2	0.9	1	1	2	2
Tribromoacetaldehyde	0.1	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND
<u>Halonitromethanes</u>											
Chloronitromethane	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromonitromethane	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dichloronitromethane	0.10	ND	ND	ND	ND	0.1	ND	ND	ND	ND	0.1
Bromochloronitromethane	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dibromonitromethane	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloropicrin[d]	0.25	ND	0.5	ND	0.3	ND	0.5	0.6	0.7	0.6	NR
Bromodichloronitromethane	0.5			ND	0.5		ND	ND			
Dibromochloronitromethane	0.5			ND	ND		ND	ND			
Bromopicrin	0.5			ND	ND		ND	ND			
<u>Miscellaneous Compounds</u>											
Methyl ethyl ketone	0.5	2	ND	ND	ND		ND	ND	ND	ND	
Methyl *tertiary* butyl ether	0.2	ND	ND	ND	ND		ND	ND	0.7	1	
Benzyl chloride	0.5	ND	ND	ND	ND	NR	ND	ND	ND	ND	NR
1,1,2,2-Tetrabromo-2-chloroethane	0.11	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

[p]<0.2 = Less than MRL (0.2 µg/L)

[q]<1 = Less than MRL (e.g., 1 µg/L)

Table 23. DBP results at plant 9 (2/25/02)

02/25/2002	MRL[a]	Plant 9[k]								
Compound	µg/L	Raw	1° Cond	Basin #6	Filt Inf	Finished	DS/Ave	DS/Max	SDS/Ave	SDS/Max
Halomethanes										
Chloromethane	0.2	ND[c]	ND	ND		ND	ND		ND	
Bromomethane	0.2	ND	ND	ND		ND	ND		ND	
Bromochloromethane	0.5	ND	ND	ND		ND	ND		ND	
Dibromomethane	0.5	ND	ND	ND		ND	ND		ND	
Chloroform[d]	0.2	ND	3	1	NR[e]	2	4	NR	2	1
Bromodichloromethane[d]	0.2	ND	4	2	NR	2	3	NR	3	2
Dibromochloromethane[d]	0.2	ND	2	1	NR	2	1	NR	2	1
Bromoform[d]	0.2	ND	0.4	<0.2[p]	NR	0.3	0.3	NR	0.4	0.2
THM4[f]		ND	9	4	NR	6	8	NR	7	4
Dichloroiodomethane	0.5	ND	<0.5[o]	<0.5	NR	<0.5	0.5	NR	<0.5	ND
Bromochloroiodomethane	0.5	ND	<0.5	<0.5	ND	<0.5	<0.5	ND	<0.5	ND
Dibromoiodomethane	0.5	ND	ND	ND	NR	ND	ND	NR	ND	ND
Chlorodiiodomethane	0.1	ND	ND	ND	ND	ND	ND	0.6	ND	ND
Bromodiiodomethane	0.52	ND	ND	ND	ND	ND	ND	ND	ND	ND
Iodoform	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND
Carbon tetrachloride	0.2	ND	ND	ND		ND	ND		ND	
Tribromochloromethane	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND
Haloacetic acids										
Monochloroacetic acid[d]	2		ND	ND		ND	ND		ND	
Monobromoacetic acid[d]	1		ND	ND		ND	ND		ND	
Dichloroacetic acid[d]	1		6.2	4.0		4.9	7.6		4.5	
Bromochloroacetic acid[d]	1		3.7	2.4		3.0	2.6		3.4	
Dibromoacetic acid[d]	1		3.0	2.2		2.7	2.2		1.8	
Trichloroacetic acid[d]	1		1.1	ND		ND	1.3		ND	
Bromodichloroacetic acid	1		1.2	ND		ND	ND		ND	
Dibromochloroacetic acid	1		ND	ND		ND	ND		ND	
Tribromoacetic acid	2		ND	ND		ND	ND		ND	
HAA5[g]			10	6.2		7.6	11		6.3	
HAA9[h]			15	8.6		11	14		10	
DXAA[i]			13	8.6		11	12		10	
TXAA[j]			2.3	ND		ND	1.3		ND	
Haloacetonitriles										
Chloroacetonitrile	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromoacetonitrile	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dichloroacetonitrile[d]	0.2	ND	0.4	ND	NR	0.2	ND	NR	ND	0.2
Bromochloroacetonitrile[d]	0.2	ND	0.8	ND	NR	0.2	ND	NR	ND	0.4
Dibromoacetonitrile[d]	1.0	ND	<1[q]	<1	<1	<1	ND	<1	<1	<1
Trichloroacetonitrile[d]	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromodichloroacetonitrile	0.5	ND	ND			ND				ND
Dibromochloroacetonitrile	0.5	ND	ND			ND				ND
Tribromoacetonitrile	0.96	ND	ND			ND				ND
Haloketones										
Chloropropanone	0.5	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloropropanone[d]	1.0	ND	<1	ND	NR	ND	ND	NR	ND	ND
1,3-Dichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dibromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1-Trichloropropanone[d]	0.5	ND	0.5	ND	NR	ND	ND	NR	ND	ND
1,1,3-Trichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
1-Bromo-1,1-dichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1-Tribromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,3-Tribromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,3,3-Tetrachloropropanone	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1,3-Tetrachloropropanone	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,3,3-Tetrabromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND

Table 23 (continued)

02/25/2002	MRL[a]	Plant 9[k]								
Compound	µg/L	Raw	1^{O} Cond	Basin #6	Filt Inf	Finished	DS/Ave	DS/Max	SDS/Ave	SDS/Max
Haloacetaldehydes										
Dichloroacetaldehyde	0.98	ND	1	2	2	2	2	2	2	3
Bromochloroacetaldehyde	0.5	ND	ND	ND	ND	ND	<0.5	ND	ND	0.5
Chloral hydrate[d]	0.1	0.5	0.4	0.2	0.3	0.1	0.5	0.1	0.2	0.7
Tribromoacetaldehyde	0.1	<1	ND	ND	ND	ND	<1	ND	ND	<1
Halonitromethanes										
Chloronitromethane	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromonitromethane	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dichloronitromethane	0.10	ND	ND	ND	ND	ND	0.1	ND	ND	ND
Bromochloronitromethane	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dibromonitromethane	0.10	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloropicrin[d]	0.25	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromodichloronitromethane	0.5	ND	0.6			0.6				0.9
Dibromochloronitromethane	0.5	ND	0.6			0.6				0.9
Bromopicrin	0.5	ND	ND			ND				ND
Miscellaneous Compounds										
Methyl ethyl ketone	0.5	ND	ND	ND		ND	ND		ND	
Methyl *tertiary* butyl ether	0.2	ND	ND	ND		ND	ND		ND	
Benzyl chloride	0.5	ND	ND	ND	NR	ND	ND	NR	ND	ND
1,1,2,2-Tetrabromo-2-chloroethane	0.11	ND	ND	ND	ND	ND	ND	ND	ND	ND

Haloacids. At plant 10 in January and April 2001, chlorine and/or chloramine disinfection resulted in the formation of 83-95, 77-90, and 42-51 µg/L of the five regulated haloacetic acids (HAA5) in the Aldrich purification units, in basins 4 and 5, and in basins 1 and 2, respectively. As with the THM results, less HAAs were produced in basins 1 and 2 in January and April 2001 because of the earlier addition of ammonia to form chloramines. Chlorine only disinfection in September 2001 resulted in the formation of 165, 149, and 147 µg/L of HAA5 in the Aldrich purification units, in basins 4 and 5, and in basins 1 and 2, respectively. In contrast, the use of chloramines only at plant 10 in November 2001 and February 2002 resulted in the formation of 21-24 µg/L of HAA5 in the Aldrich purification units and in basins 4 and 5.

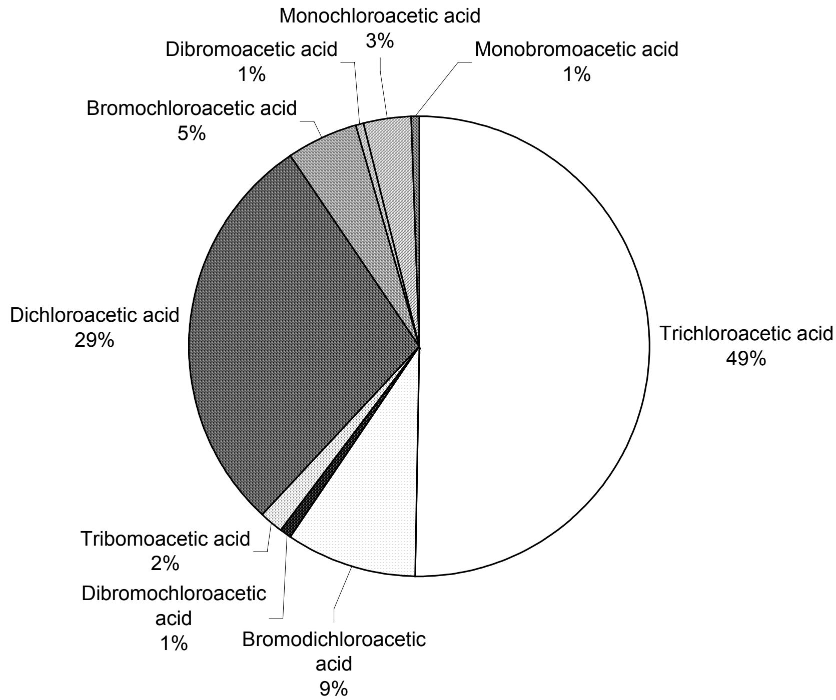
At plant 9 in January 2001, April 2001, August 2001, November 2001, and February 2002, chlorine/chloramine disinfection resulted in the formation of 4-18 µg/L of HAA5. Higher formation of HAAs was observed in April and August as compared to in January 2001, with intermediate HAA formation in November 2001 and February 2002.

In addition, all nine HAAs (HAA9) were measured, which included all of the brominated HAA species. At plant 10, the level of HAA9 in the Aldrich purification units, in basins 4 and 5, and in basins 1 and 2, was 104-114, 92-114, and 52-61 µg/L, respectively, in January and April 2001 and was 177-198 µg/L in September 2001. In contrast, with chloramines only, HAA9 was 24-30 µg/L in November 2001 and February 2002 in the Aldrich Purification units and in basins 4 and 5. At plant 10, HAA formation was higher than THM formation. At plant 9, the level of HAA9 in the finished water was 6-21 µg/L.

When pre-chlorination was used at plant 10 (January, April, and September 2001), trihalogenated HAAs (TXAAs) were in higher proportion than the dihalogenated species (DXAAs) (e.g., 111 versus 61 µg/L in basins 4&5 in September 2001). In other research, TXAAs were found to constitute the greatest mole fraction of HAA9 in chlorinated waters at pH 8 (Cowman and Singer, 1996). (The plant 10 waters were chlorinated at pH levels in the range of 7 to 8.) When pre-chloramination was used at plant 10 (November 2001 and February 2002), DXAAs were in higher proportion than the TXAAs (e.g., 16 versus 5 µg/L in basins 4&5 in November 2001). In other research, chloramines have been shown to produce little or no THMs and TXAAs, whereas DXAAs formed (Krasner et al., 1996). With either pre-chlorination or pre-chloramination at plant 10, in each HAA subgroup (monohalogenated HAAs [MXAAs], DXAAs, TXAAs), the fully chlorinated species (monochloro-, dichloro-, and trichloroacetic acid) predominated, followed by the bromochloro species (bromochloro- and bromodichloroacetic acid) (Figure 4).

At plant 9, most of the HAAs that were formed were DXAAs; very low amounts of TXAAs were detected (Figure 5). In other research, pH (in the range of 5 to 9.4) had no significant effect on dichloroacetic acid formation, whereas trichloroacetic acid formation was lower at pH 9.4 than at the lower pH levels (and THM formation was higher with increasing pH) (Stevens et al., 1989). The THM and HAA (DXAA versus TXAA) data (Figure 5) suggest the following: (1) minimal free chlorine contact time and the very high pH of chlorination (typically ~10) initially impacted the DBP formation and speciation; and (2) the presence of chloramines in

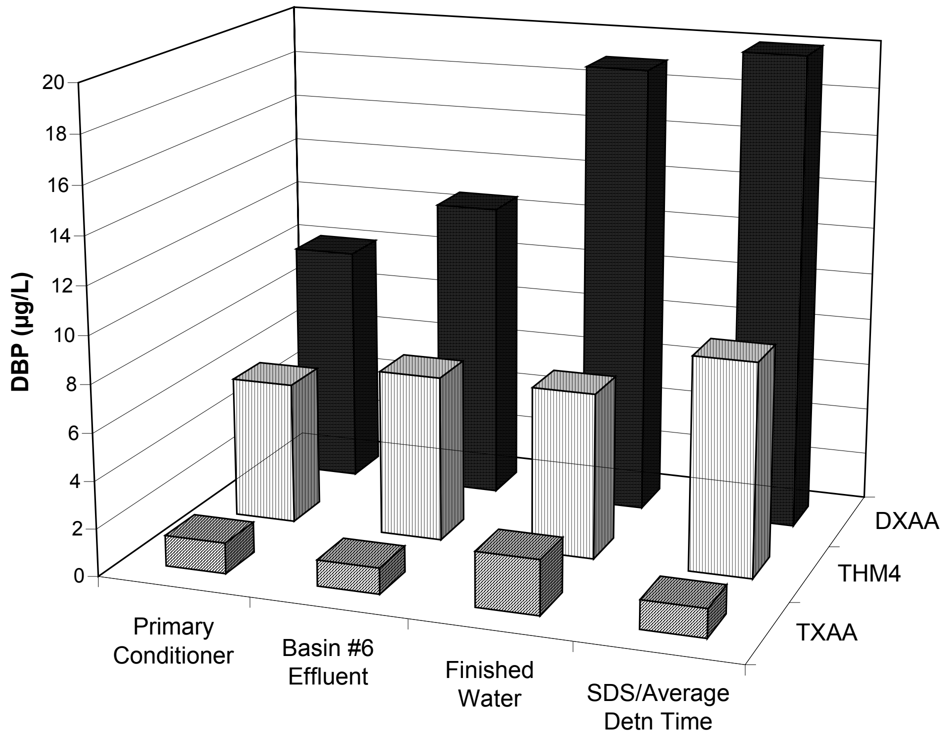
Figure 4. HAA speciation in Basins 4&5 at plant 10 in September 2001



the downstream basins minimized further THM and TXAA formation but allowed DXAAs to continue to form.

In other research, it was demonstrated that HAAs can be removed by GAC filtration, presumably by biodegradation processes within the filter bed (Singer et al., 1999). The extent of removal depended upon water temperature and the residual chlorine concentration. Because the combined filter effluent at the conventional plant was a combination of water from basins 4&5 and basins 1&2, the filter effluent was compared to a flow-weighted filter influent. For example, in April 2001, basins 4&5 had a flow of 20.6 mgd and 43 μg/L of DXAAs, and basins 1&2 had a flow of 11 mgd and 27 μg/L of DXAAs. So the flow-weighted filter influent had 37 μg/L of DXAAs: (20.6 x 43 + 11 x 27)/(20.6 + 11). Figure 6 shows the seasonal variations in HAA removal through the GAC filters. In January 2001, HAAs were not removed when the water temperature was 0.3-3.5ºC. In April 2001, when the water temperature was 14-15ºC, the DXAAs were reduced in concentration by 35 %, whereas the levels of the other two subclasses of HAAs were relatively constant. In September 2001, when the water temperature was 27-29ºC, the DXAAs were reduced in concentration by 75 % and the MXAAs were not detected (ND) in the filter effluent, whereas the level of TXAAs was marginally reduced. In November 2001, when the water temperature was 13-16ºC, the DXAAs and MXAAs were reduced in concentration by 61 and 64 %, respectively, whereas the level of TXAAs was marginally reduced. In February 2002, HAA data were not available for basins 1&2. Because most of the

Figure 5. Impact of chloramines and pH of chlorination (~10) on THM and HAA formation and speciation at plant 9: August 27, 2001



flow in the conventional treatment train was from basins 4&5, the data for the former basins were used to estimate the combined filter influent concentrations. In the latter month, when the water temperature was 6ºC, the DXAAs and TXAAs were not removed, and the MXAAs were not detected (ND) in the filter effluent. These results are consistent with other research in which DXAAs were found to be biodegradable, whereas TXAAs were not, and the phenomenon was temperature dependent (Baribeau et al., 2000).

Figure 6. Seasonal variations in removal of HAAs through GAC filters at plant 10: water temperature at filters provided by each sample date (ND = not detected in filter effluent)

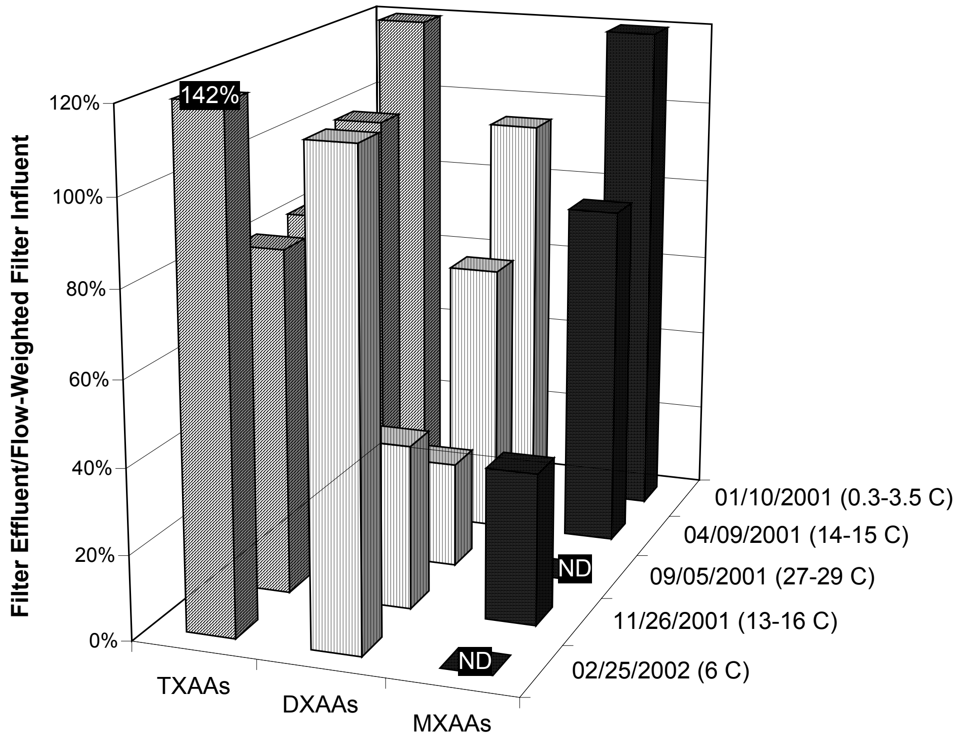
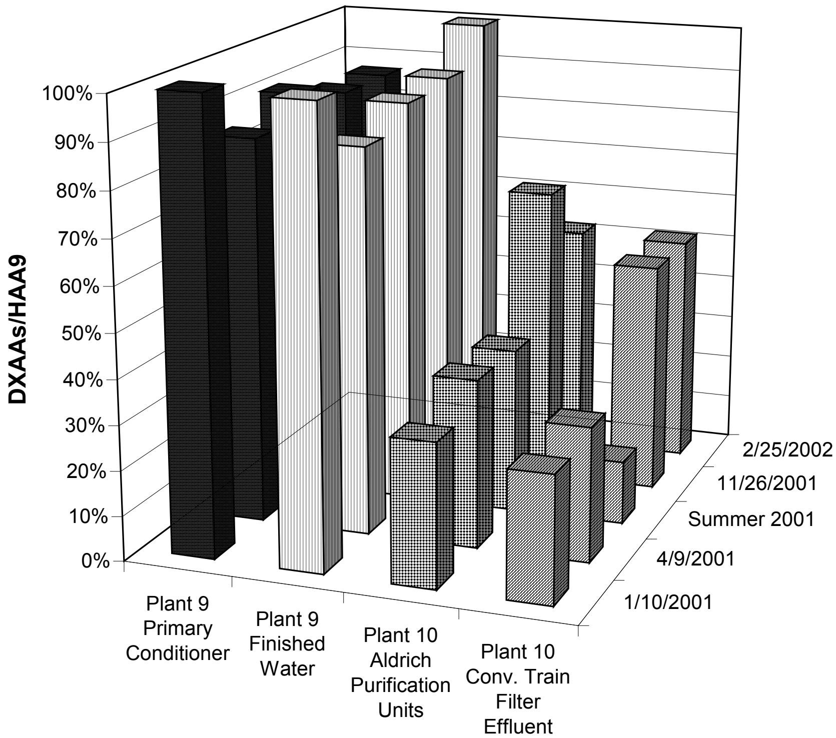


Figure 7 shows a comparison of DXAA and TXAA speciation at the two Mississippi River WTPs. The use of either chloramines or disinfection at pH levels of ≥ 9 favored DXAA formation over TXAA formation at plant 9, whereas pre-chlorination at pH 7-8 at plant 10 (January, April, and summer 2001) resulted in somewhat more TXAA formation than DXAA formation. Alternatively, pre-chloramination at pH 7-8 at plant 10 (November 2001 and February 2002) resulted in somewhat more DXAA formation than TXAA formation. Also, GAC filtration (in the conventional treatment trains) at plant 10 was more effective at removing DXAAs than TXAAs (especially in summer 2001). Thus, the difference in HAA speciation at these two utilities reflected the different effects of chlorine and chloramines, as well as pH and GAC filtration, on HAA formation and control.

Figure 7. Impact of chloramines and chlorine, pH and GAC filtration on HAA speciation at plant 9 and plant 10



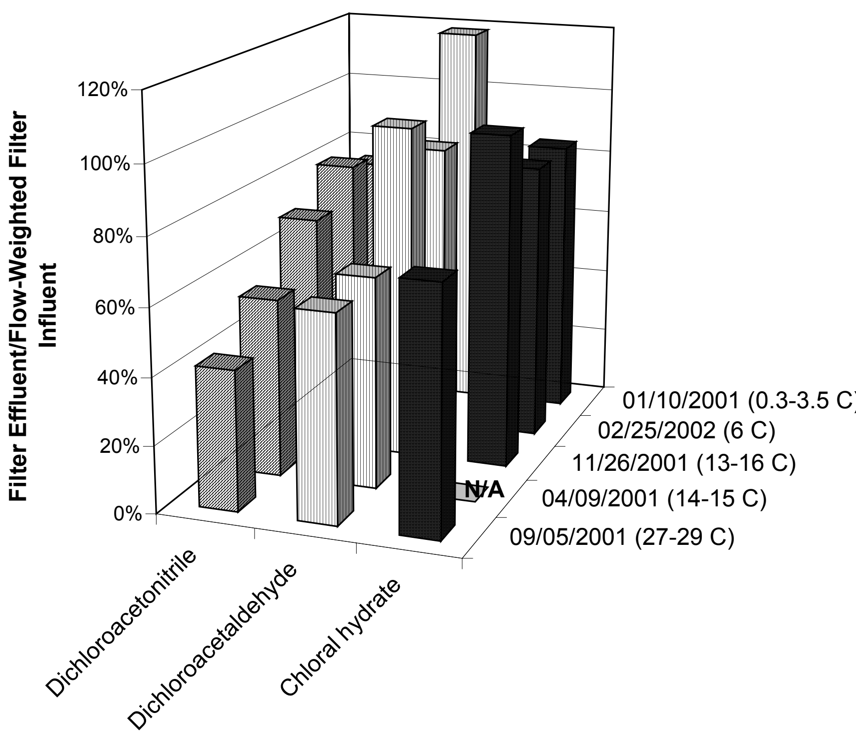
In addition to the target HAAs, two other haloacids were detected at plant 10 in April 2001 by the broadscreen GC/MS methods: 3,4,4-trichloro-3-butenoic acid and *cis*-2-bromo-3-methylbutenedioic acid (Table 15). November 2001 results from UNC also show the presence of another target halo-acid, 3,3-dichloropropenoic acid, at a level of 0.4 µg/L in finished waters from plant 10 (Table 20).

Haloacetonitriles. In other research, haloacetonitriles (HANs) have been found to be produced at approximately one-tenth the level of the THMs (Oliver, 1983). In the plant 10 samples, a comparison was made between the four HANs in the Information Collection Rule (ICR) (HAN4) (dichloro- [DCAN], bromochloro-, dibromo-, and trichloroacetonitrile [TCAN]) and THM4. The ratio of HAN4 to THM4 (on a weight basis) for the January, April, and September 2001 samplings was 8, 15, and 16 %, respectively.

A similar relationship was also observed (in part) in the plant 9 samples. Because the THM concentrations were at low µg/L levels at plant 9, the ICR HANs were detected at sub-µg/L levels. The major HAN formed, DCAN, typically went down in concentration in the plant, distribution system, and/or SDS samples. DCAN undergoes base-catalyzed hydrolysis (Croué and Reckhow, 1989), so it is not surprising that it would not be stable at the pH of treatment and distribution at plant 9 (i.e., pH = 9-10).

Similar to the HAAs (Figure 6), seasonal variations in the removal of DCAN through GAC filters was evaluated (Figure 8). In January 2001 and February 2002, the concentration of DCAN was 74-80 % of the level in the flow-weighted filter influent. In April and November 2001, when the water temperature was warmer, DCAN was reduced in concentration by 30-47 %. In September 2001, when the water temperature was the warmest, DCAN was reduced in concentration by 58 %. These results are similar to the seasonal removal of DXAAs (Figure 6).

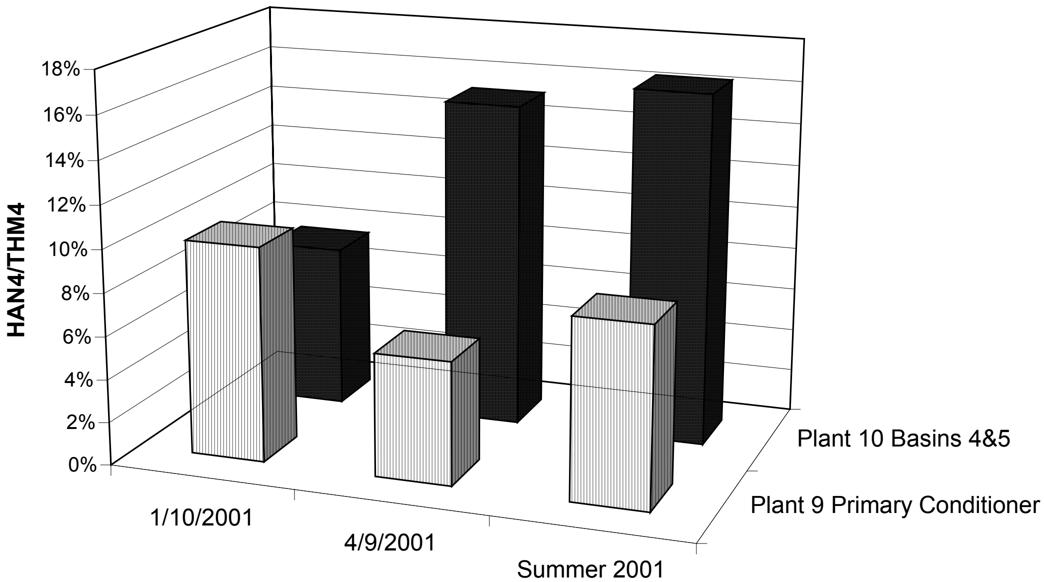
Figure 8. Seasonal variations in removal of other DBPs through GAC filters at plant 10: water temperature at filters provided by each sample date (results arranged in order of decreasing water temperature); N/A = not available



A comparison of HAN formation was made between the primary conditioner at plant 9 (at the beginning of the treatment process, prior to downstream base-catalyzed hydrolysis) and the effluent of basins 4&5 at plant 10 (before GAC filtration) for January, April, and November 2001 (Figure 9). The ratio of HAN4 and THM4 (on a weight basis) was 6-10 % at plant 9 and 8-16 % at plant 10. The ratio was somewhat higher at plant 10, probably because of the lower pH of chlorination, which minimized base-catalyzed hydrolyis of the HANs.

In addition to the ICR HANs, other target HANs (chloro-, bromo-, bromodichloro-, and dibromochloroacetonitrile) were detected in selected samples at plant 10. (The latter HAN was detected during the broadscreen GC/MS analyses [Table 15]). None of the other target HANs were detected at plant 9.

Figure 9. Relative formation of HANs to THMs at the Mississippi River WTPs



Haloketones. In addition to the formation of low levels of haloketone (HK) compounds from the ICR (1,1-dichloro- and 1,1,1-trichloropropanone), low levels of some of the target HKs were detected in some of the samples at plant 9 and plant 10 (Figure 10). At plant 10, the formation of 1,1,1-trichloropropanone was much higher, especially when pre-chlorination was utilized (e.g., April 2001). In other research, 1,1,1-trichloropropanone was detected at acidic and neutral pH levels, but was not detected at a pH of 9.4 (Stevens et al., 1989). Thus, the presence of chlorine for longer contact times at a lower pH level resulted in more formation of this HK at plant 10. Alternatively, 1,1-dichloropropanone levels were comparable at both plants in April 2001, suggesting that pH did not impact this HK to the same extent. When pre-chlorination was used at plant 10, the level of 1,1,1-trichloropropanone was much higher than that of 1,1-dichloropropanone, whereas when pre-chloramination was used the levels of the two HKs were similar (Figure 10).

Figure 11 shows the impact of distribution-system disinfectant on the formation and stability of THMs and HKs at plant 10, comparing the SDS samples set up for a maximum detention time (five days) to the original finished water. In April 2001, when chloramines were used, the concentrations of the THMs and many of the HKs were relatively constant. However, there was a significant increase in the formation of 1,1-dichloropropanone. In other research, chloramines were found to control the formation of THMs and TXAAs better than they control the formation of DXAAs (Krasner et al., 1996). Thus, 1,1-dichloropropanone may continue to form in chloraminated water. In September 2001, when chlorine was used, the concentration of

Figure 10. Haloketone formation in finished waters at plant 9 (4/9/01) and plant 10 (4/9/01 and 11/26/01) (haloketones not detected in finished water at plant 9 on 11/26/01)

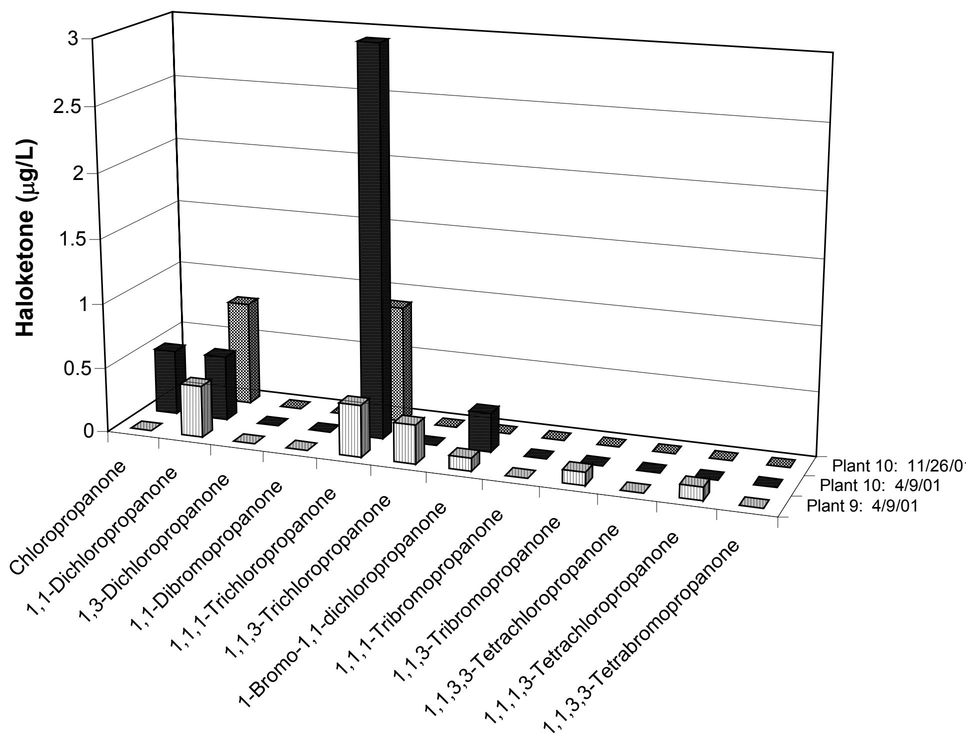
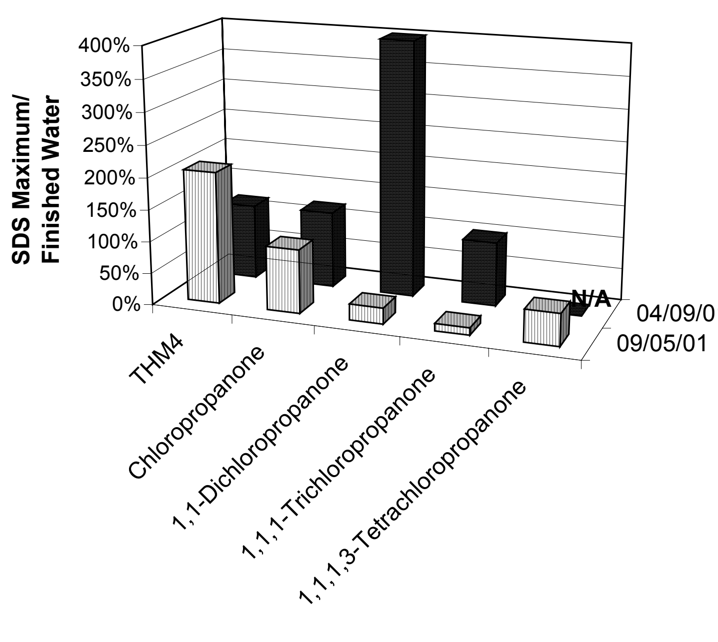


Figure 11. Plant 10 (N/A = not available):



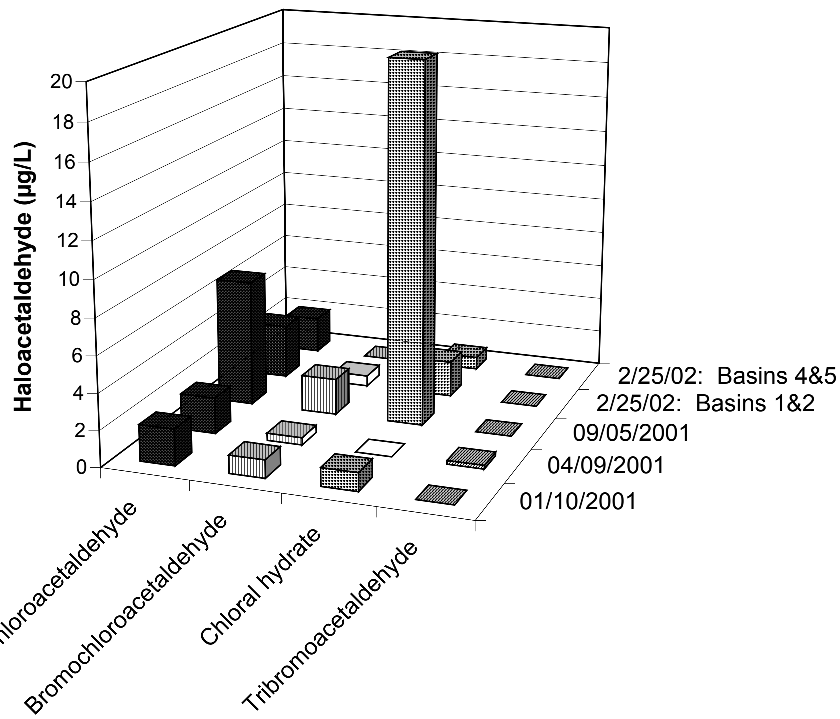
the THMs significantly increased, the concentration of chloropropanone was unchanged, and the concentrations of some of the other HKs decreased to varying degrees, especially that of 1,1,1-trichloropropanone (from 7 to 0.8 μg/L). In other research, 1,1,1-trichloropropanone was shown to decrease in the presence of chlorine, perhaps as a result of the direct reaction of chlorine with this HK (Reckhow and Singer, 1985).

In addition to the target HKs, other HKs were detected in selected samples by the broadscreen GC/MS methods (Table 15). Two of these HKs were analogous to the di- and tetrahalogenated HKs monitored for by MWDSC, except that these were mixed bromochloro species. Another two HKs that were detected at these WTPs by the broadscreen GC/MS methods was pentachloro- (PCP) and hexachloropropanone (HCP). MWDSC had attempted to include PCP and HCP in its target compound list, but they both degraded immediately and completely in water under all conditions evaluated (Gonzalez et al., 2000).

Haloaldehydes. In addition to the formation of chloral hydrate (trichloroacetaldehyde) (an ICR DBP), low levels of the target haloacetaldehydes (e.g., dichloroacetaldehyde) were detected at plant 10 (Figure 12). In January 2001, April 2001, and February 2002, chloraminated water was in settling basins 1&2 (with upstream pre-chlorination in mixing tank number 2) (Figure 1), whereas in September 2001, chlorine only was in settling basins 1&2. The sum of the concentration of the two dihalogenated acetaldehydes (2.4-3.6 μg/L) was greater than the sum of the concentration of the two trihalogenated acetaldehydes (0.2-2 μg/L) when the water was chloraminated. When the water was chlorinated, chloral hydrate formation (22 μg/L) was much greater than the formation of the sum of the two dihalogenated acetaldehydes (9 μg/L). In addition, the warmer water temperature in September 2001 contributed to more haloacetaldehyde formation overall.

In February 2002, pre-chloramination in basins 4&5 versus chlorine/chloramines in basins 1&2 resulted in much more control of chloral hydrate (0.7 versus 2 μg/L) than for dichloroacetaldehyde (2 versus 3 μg/L). In other research, chloramines were found to minimize the formation of chloral hydrate, whereas certain dihalogenated DBPs were formed to greater extents (Young et al., 1995). Consistent with that research, the formation of dihalogenated acetaldehydes was favored over trihalogenated species at plant 10 when chloramines were used, especially with pre-chloramination.

Figure 12. Haloacetaldehyde formation and speciation in Basins 1&2 at plant 10: chlorine/chloramines in January 2001, April 2001, and February 2002; chlorine only in September 2001 (Basins 4&5 with pre-chloramination in February 2002 provided for comparison)



At plant 9, dichloroacetaldehyde formation was typically greater than that of chloral hydrate (Figure 13). This was due, in part, because chloral hydrate undergoes base-catalyzed hydrolysis at high pH (e.g., ~9) (Stevens et al., 1989). With the measurement of dihalogenated and/or brominated analogues of chloral hydrate, the haloacetaldehydes represented the third largest class of DBPs formed at plant 9 (on a weight basis).

Figure 13. Seasonal variations in the formation and speciation of the haloacetaldehydes in the finished water of plant 9

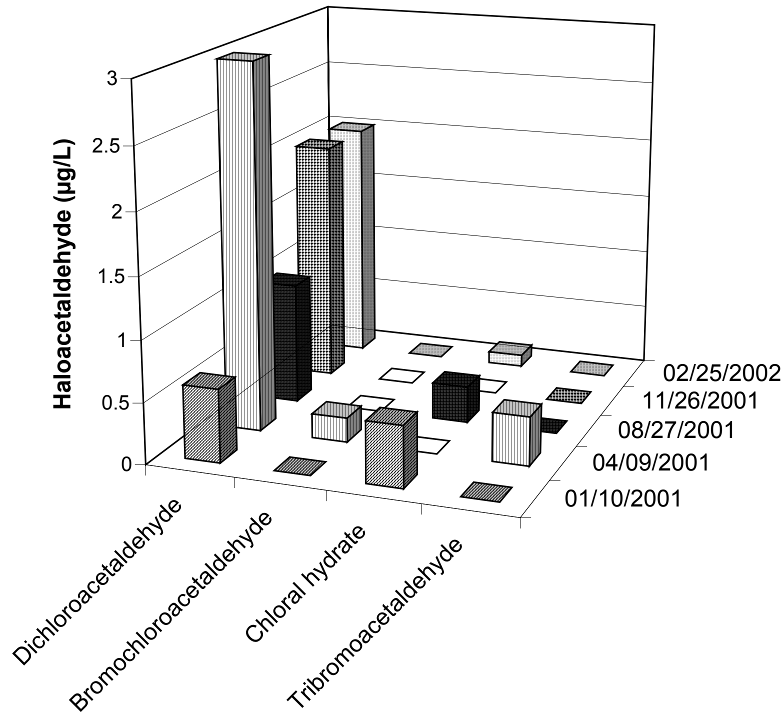
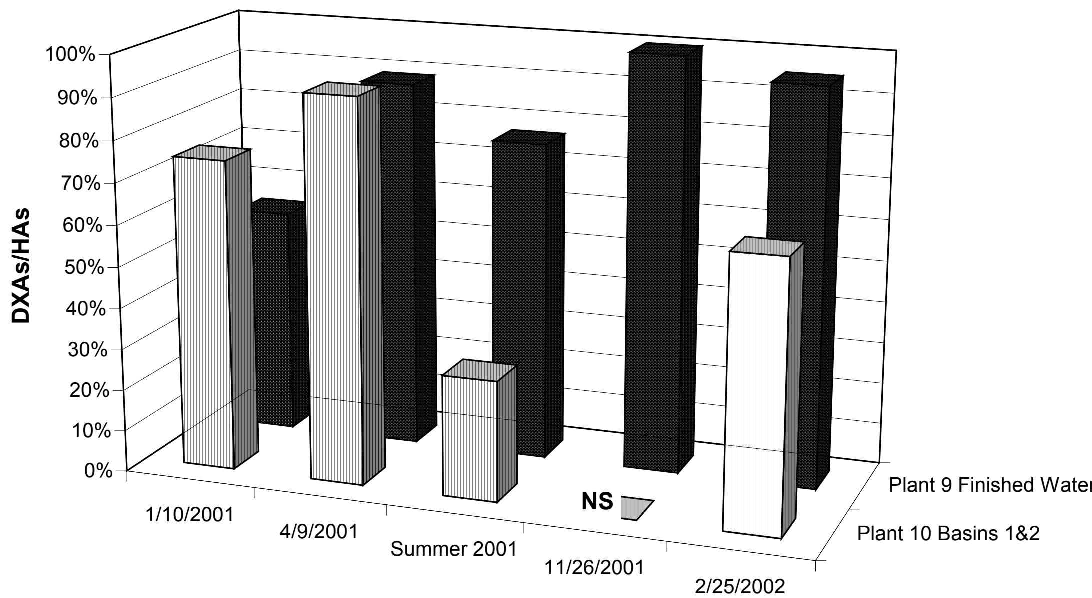


Figure 14 shows the relative speciation of the sum of the two measured dihalo-acetaldehydes (DXAs) to the sum of the four measured species. At plant 9, DXAs represented 55 to 100 % (median = 89 %) of the measured haloacetaldehydes (HAs). At plant 10, the DXAs represented 64 to 92 % of the haloacetaldehydes in basins 1&2 when chloramines were used and 29 % of this class of DBPs when chlorine only was used. In February 2002, when pre-chloramination was used in basins 4&5, the DXAs represented 74 % of the haloacetaldehydes (Figure 12).

As with the other classes of DBPs, the formation of the chlorinated species at plant 10 was highest for each subclass of haloacetaldehyde, and the bromochloro species was next highest in concentration (Figure 12).

Figure 14. Impact of chloramines and chlorine, and pH on haloacetaldehyde (HA) speciation (e.g., dihaloacetaldehydes [DXAs]) at the Mississippi River WTPs (NS = not sampled)

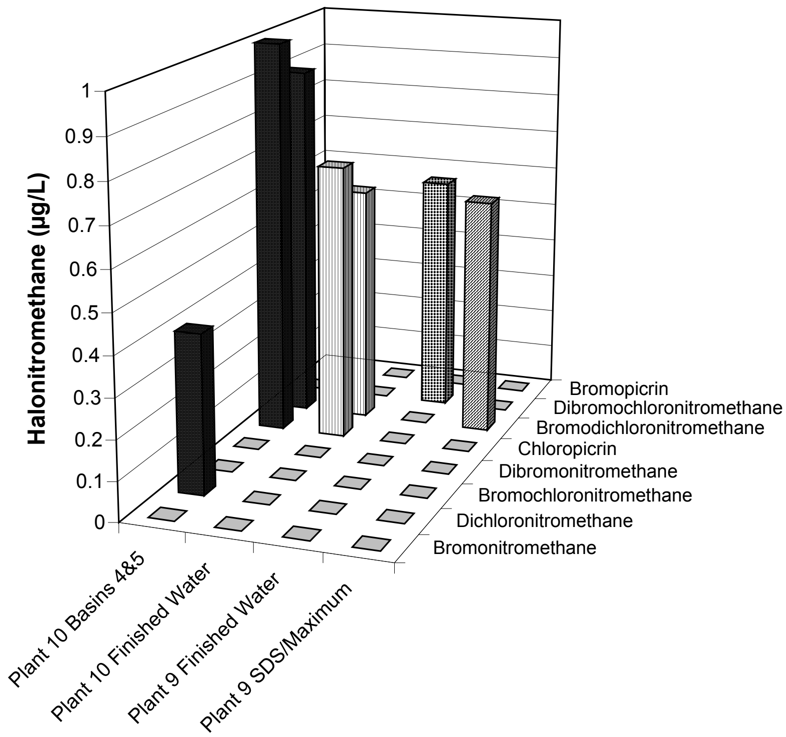


Similar to the HAAs (Figure 6) and DCAN (Figure 8), seasonal variations in the removal of dichloro- and trichloroacetaldehyde [chloral hydrate]) were examined (Figure 8). In January 2001 and February 2002, the concentrations of these two haloacetaldehydes were 84-119 % of the levels in the flow-weighted filter influents. In April 2001, when the water temperature was warmer, dichloroacetaldehyde was reduced in concentration by 37 % (data were not available (N/A) for chloral hydrate). However, in November 2001, when the water temperature was similar to that in April 2001, there was no reduction in the concentration of the haloacetaldehydes though the GAC filters. In September 2001, when the water temperature was the warmest, dichloroacetaldehyde and chloral hydrate were reduced in concentration by 39 and 27 %, respectively. These results are similar, in part, to the relative seasonal removal of DXAAs and TXAAs (Figure 6) and DCAN (Figure 8).

In addition to the target haloaldehydes, one other haloaldehyde was detected at both WTPs by the broadscreen GC/MS methods: 2-bromo-2-methylpropanal (Table 15).

Halonitromethanes. Low levels of chloropicrin (trichloronitromethane) (an ICR DBP) were detected at plant 10. This DBP was only detected in the April and November 2001 samples at plant 9. Other halonitromethanes (HNMs) were detected in selected samples from both WTPs

Figure 15. Halonitromethane formation at the Mississippi River WTPs in August/September 2001

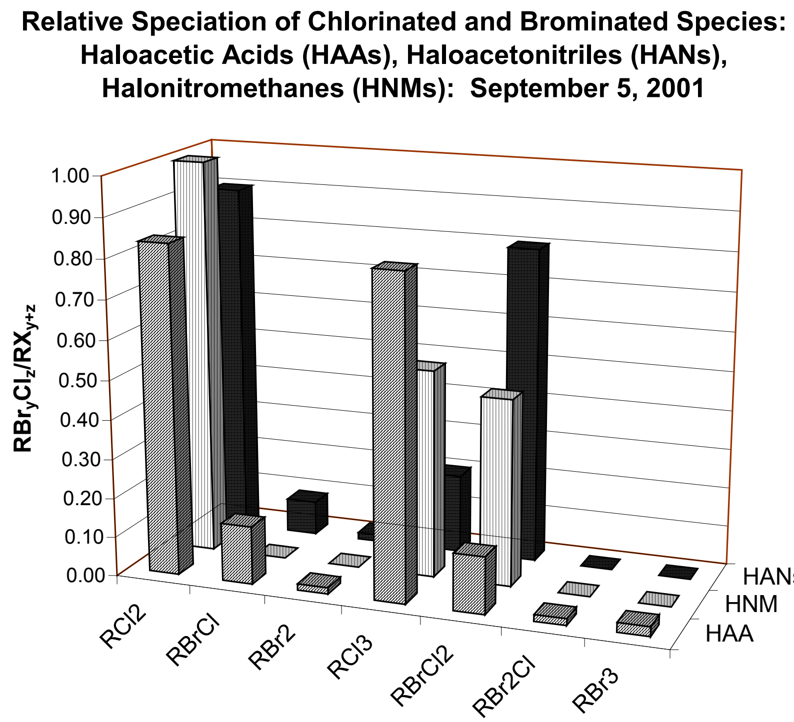


(e.g., Figure 15). Although there was a large difference in THM and HAA formation between the two utilities, the difference in HNM formation was not as high.

As with the HAAs, there are nine HAN species and nine NHMs (two monohalogenated species, three dihalogenated species, and four trihalogenated species). The relative speciation of brominated and chlorinated HANs and HNMs (for the di- and trihalogenated species) was compared to the HAAs for the effluent of basins 4&5 from the September 2001 sampling. Each DBP can be abbreviated based on the number of halogens and the speciation of the halogens as follows: RBr_yCl_z, where the number of bromine and chlorine atoms are y and z, respectively, and R corresponds to the remainder of the DBP molecule (i.e., carbon, hydrogen, oxygen, and nitrogen atoms). The concentration of each DBP was "normalized" by dividing its concentration by the sum of the concentrations of all of the DBPs for that "subclass" of DBPs (RX_{y+z}) (Figure 16). For example, the concentration of dichloroacetic acid was divided by the sum of all the DXAAs.

For the dihalogenated DBPs (RX_2), the dichlorinated species represented 84 to 100 % of the sum of the dihalogenated DBPs in each class of DBPs examined. The bromochloro species represented 0 to 15 % of the class sums, and the dibromo species represented 0 to 2 % of the class sums. For the HAAs, HANs, and HNMs, there was a similar relative speciation of brominated and chlorinated DBPs for the dihalogenated subclass. For the trihalogenated DBPs (RX_3), the trichlorinated, bromodichlorinated, dibromochlorinated, and tribrominated species

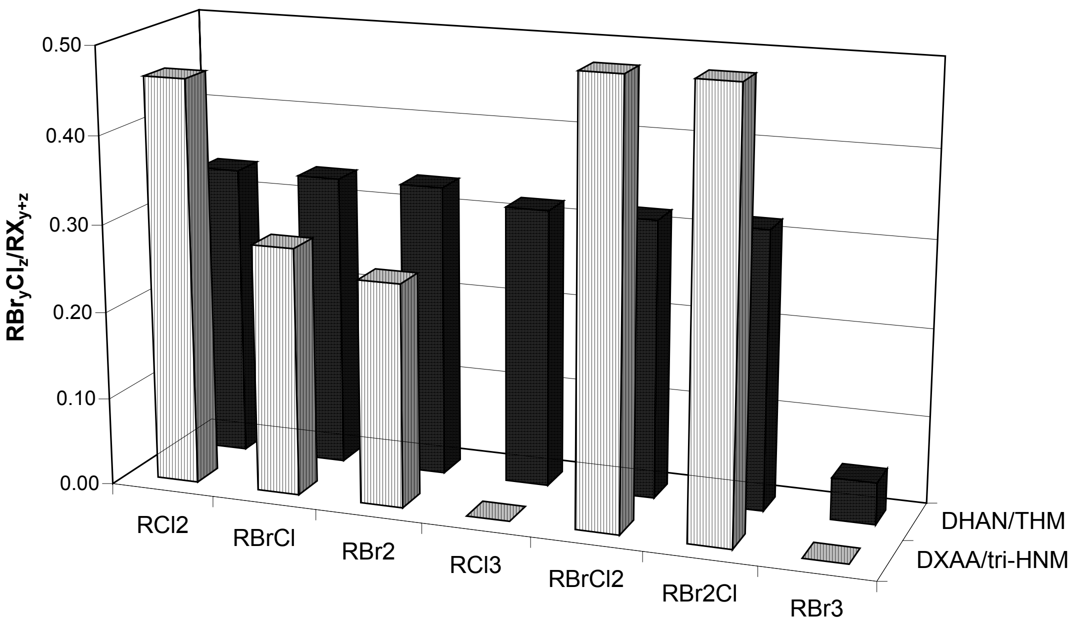
Figure 16. Effluent of Basins 4&5 at plant 10:



represented 20 to 81 %, 14 to 80 %, 0 to 2 %, and 0 to 2 % of the subclass sums, respectively. Although not shown in this figure, for THM4, chloroform, bromodichloromethane, dibromochloromethane, and bromoform represented 69, 28, 3, and 0 % of that class sum, respectively. The relative speciation of the THMs was in between that of the speciation for the HAAs and the HNMs. The reason the relative speciation for the trihalogenated HANs may have been different is probably due to the relative instability of TCAN. In other research, TCAN has been shown to undergo base-catalyzed hydrolysis in the pH range of 7 to 8, whereas it is stable at pH 6 (Croué and Reckhow, 1989). The pH of basins 4&5 was 7.2, so it is likely that TCAN simultaneously formed and degraded in these basins.

For plant 9, the relative speciation of brominated and chlorinated HNMs (for the trihalogenated species) was compared to the THMs, the dihaloacetonitriles (DHANs), and the DXAAs for the February 2002 finished water (Figure 17). (TXAAs and dihalogenated HNMs were not detected in this sample.) For the RX_2, the dichlorinated species represented 33 to 46 % of the sum of the dihalogenated DBPs in that subclass of DBPs (on a weight basis). The bromochloro species represented 28 to 33 % of the subclass sum, and the dibromo species represented 25 to 33 % of the subclass sum. For the RX_3, the trichlorinated, bromodichlorinated, dibromochlorinated, and tribrominated species for the HNMs and THMs represented 0 to 32 %, 32 to 50 %, 32 to 50 %, and 0 to 5 % of the class sum, respectively. In February 2002, the raw-water bromide level was the highest for the plant 9 samples. For the THMs, HAAs, DHANs, and HNMs, there was a similar relative speciation of brominated and chlorinated DBPs at plant 9, with a shift to more of the brominated species.

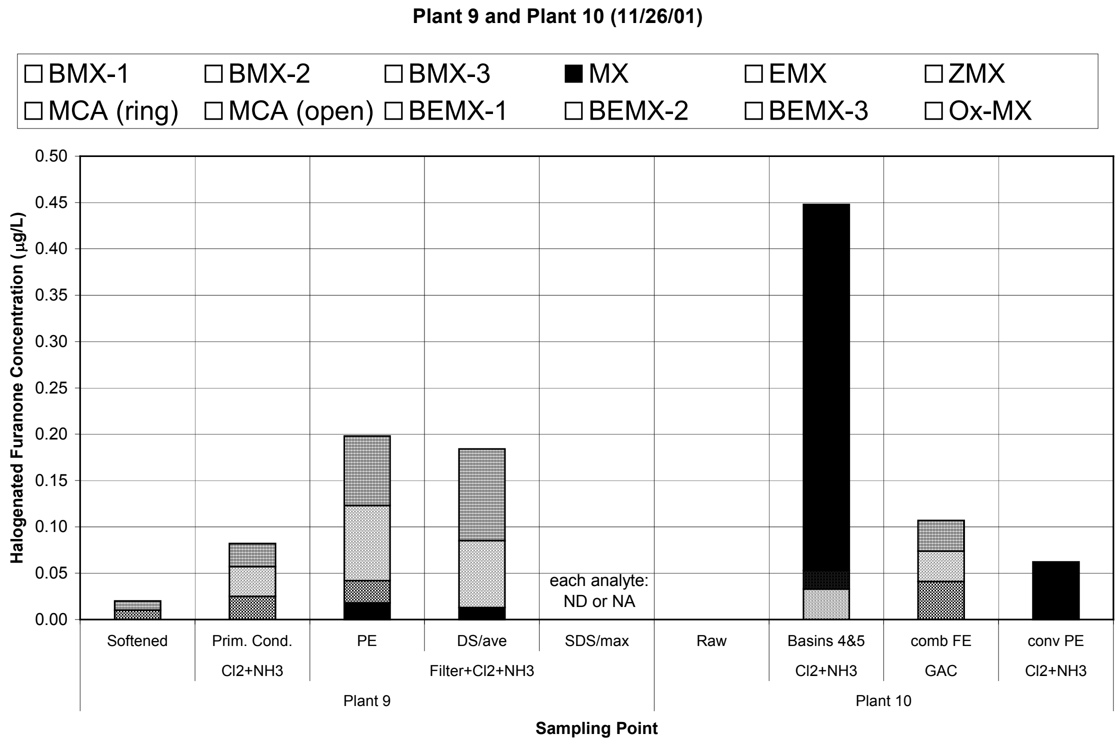
Figure 17. Relative speciation of chlorinated and brominated species in finished water at plant 9 (2/25/02): dihaloacetic acids (DXAAs), dihaloacetonitriles (DHANs), trihalomethanes (THMs), trihalogenated halonitromethanes (tri-HNMs)



Halogenated furanones. Table 21 shows the results for halogenated furanones in the November 2001 sampling for plant 9 and plant 10. Data are included for 3-chloro-4-(dichloromethyl)-5-hydroxy-2[5H]-furanone, otherwise known as MX; (E)-2-chloro-3-(dichloromethyl)-4-oxobutenoic acid, otherwise known as EMX; (Z)-2-chloro-3-(dichloromethyl)-4-oxobutenoic acid (ZMX); the oxidized form of MX (Ox-MX); brominated forms of MX and EMX (BMXs and BEMXs); and mucochloric acid (MCA), which can be found as a closed *ring* or in an *open* form. Results are displayed graphically in Figure 17.

There was an increase in the concentrations of MCA-*ring* and MCA-*open* in the presence of chloramines at plant 9 (11/26/01) (Table 21). Brominated analogues of MX were not detected at plant 9. Plant 10 showed a significant formation of MX, with a levels of 400 ng/L observed after treatment with chloramines (in a sample collected from settling basins 4 & 5) (Figure 18). However, subsequent GAC filtration removed the MX, with no MX measured in the filter effluent. This is consistent with the removal of other DBPs in this study during the filtration process, which was probably due to biodegradation and not adsorption. Following the addition of chloramines after GAC filtration, MX was reformed at a significantly lower level in the plant effluent (60 ng/L). Two brominated analogues of MX (BMX-1 and BMX-3) were also formed at

Figure 18. Halogenated furanones.



plant 10 (30 and 20 ng/L, respectively), but GAC filtration was effective in removing them completely, and they were not reformed in the plant effluent samples (Table 21). In samples collected in April 2001 from plant 10, ox-MX was qualitatively identified in the plant effluent using broadscreen GC/MS analysis (Table 15).

Volatile Organic Compounds (VOCs). Carbon tetrachloride, which is a VOC and a possible DBP, was detected (0.07-0.3 µg/L) in several samples at plant 10, but was not found in the raw water (MRL = 0.06 or 0.2 µg/L). As mentioned in a previous chapter, carbon tetrachloride has been detected by some utilities in gaseous chlorine cylinders (EE&T, 2000), due to imperfections in the manufacturing process or improper cleaning procedures.

Methyl *tertiary* butyl ether (MtBE) was detected in the raw water of plant 10 on September 5, 2001 at a concentration of 1.6 µg/L. The level of MtBE decreased somewhat through plant 10. MtBE was detected (0.7-1 µg/L) in the distribution system and in SDS testing for plant 10 on February 25, 2002, but was not detected (with an MRL of 0.2 µg/L) in the raw water. MtBE was detected (0.2-0.3 µg/L) in the raw water samples for plant 9 in January and August 2001, but was not detected in the WTP samples (with an MRL of 0.2 µg/L). MtBE is a gasoline additive.

Methyl ethyl ketone (MEK) was detected in plant 9 on August 27, 2001 at 0.5-1 µg/L, but was not detected at or above the MRL of 0.5 µg/L in the raw water. MEK was detected (1 µg/L) in the raw water for plant 9 on November 26, 2001, and was detected in some downstream samples at 0.8-1 µg/L. MEK was detected in the plant 10 conventional treatment train at 0.6

μg/L on September 5, 2001, but was not detected at or above the MRL of 0.5 μg/L in the raw water. MEK was detected (2 μg/L) in the raw water for the Aldrich purification units at plant 10 on February 25, 2002, but was not detected in the treated water. MEK is an industrial solvent and it may also be a DBP. Because the level in the two WTPs in the summer 2001 samples was barely above the MRL, it can not be determined for sure if its presence was due to low-level raw-water contamination (as was observed in November 2001 at plant 9 and in February 2002 at plant 10) or if it was produced during the disinfection process.

Other Halogenated DBPs. A few additional, miscellaneous halogenated DBPs were also detected. UNC methods detected dichloroacetamide at 1.7 μg/L in finished water from plant 10 (1/10/01) (Table 12). In addition, broadscreen GC/MS analyses revealed the presence of 1,2-dichloroethylbenzene, tetrachlorocyclopentadiene, hexachlorocyclopentadiene, and bromopentachlorocyclopentadiene in finished water collected from plant 10 in April 2001 (Table 15). Dichlorophenol was identifed in finished water from plant 9 (Table 15). These compounds were not observed in the corresponding raw, untreated water.

Non-Halogenated DBPs. Very few non-halogenated DBPs were detected in finished waters from plant 10 or plant 9. Dimethylglyoxal was identified at 0.2 and 0.3 μg/L in finished waters from plant 9 and plant 10, respectively, in November 2001 (Table 20). Broadscreen GC/MS analysis revealed the presence of glyoxal and dodecanoic acid in finished water from plant 10 (April 2001), and 4-methylpentanoic acid was found in finished waters from plant 9 (August 2001) (Table 15).

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